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# FLOW OF WATER

IN

# OPEN CHANNELS

PIPES, SEWERS, CONDUITS, &C.;

WITH TABLES,

BASED ON THE

FORMULÆ OF D'ARCY, KUTTER AND BAZIN.

BY

P. J. FLYNN, CIVIL ENGINEER,

*Author of "Hydraulic Tables, Based on Kutter's Formula for Circular and Egg-Shaped Sewers."*

NEW YORK:
D. VAN NOSTRAND CO., PUBLISHERS
23 MURRAY AND 27 WARREN STREETS.
1886.

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# PREFACE.

THE formulæ of D'Arcy, Kutter and Bazin are gradually, but surely, being adopted instead of the old formulæ of D'Aubisson, De Prony, Downing, &c.

The former formulæ, however, though admitted to be more accurate, are also, as a rule, more complicated in form, and more troublesome and tedious in their application, than most of the old formulæ in use. In these days, when numerous works on Sewerage, Water Supply, Irrigation, &c., are being constructed in this country, and in fact all over the civilized world, hydraulic formulæ are, perhaps, in more general use by Engineers than at any former time, and therefore, any ready method which combines rapidity with accuracy in the application of the new formulæ will, very likely, tend to their more general use than at present.

It is believed that this combination of rapidity with accuracy can be gained by the proper use of the tables in this book; and Hydraulic Engineers, who make it a practice to use the formulæ of D'Arcy, Kutter and Bazin, and to whom a saving of time and tedious computation is an object, will find the tables of material help in the solution of problems relating to the flow of water in open and closed channels.

# CONTENTS.

Discussion on Formulæ and Tables............ 7
Explanation and Use of the Tables............ 44
Table 1, based on D'Arcy's Formula for Clean Pipes........................................ 57
Table 2, based on Kutter's Formula, with $n = .011$........................................ 62
Table 3, based on Kutter's Formula, with $n = .012$........................................ 67
Table 4, based on Kutter's Formula, with $n = .013$........................................ 72
Table 5, based on Bazin's Formula for open channels of the second category............... 77
Table 6, Values of $\sqrt{r}$ for Diameters given in Tables........................................ 79
Table 7, Slopes........................................ 81
Table 8, Comparison of Coefficients ($c$), Kutter and D'Arcy........................................ 114
Table 9, Comparison of Coefficients, Kutter, D'Arcy and Fanning........................ 116
Table 10, Comparison of Velocities, Kutter's Formula and Tables............................. 117
Table 11, Comparison of Velocities, Kutter's Formula and Tables............................. 118

# FLOW OF WATER IN OPEN CHANNELS,

## *PIPES, SEWERS, CONDUITS, &c.*

In the following formulæ let—

V = velocity in feet per second.

Q = discharge in cubic feet per second.

C = coefficient of mean velocity.

S = fall of water surface ($h$), in any distance ($l$), divided by that distance $= \frac{h}{l} =$ sine of slope.

$a$ = area of cross-section of pipe, conduit or open channel in square feet.

$p$ = wetted perimeter of pipe, conduit or open channel in lineal feet.

$r$ = hydraulic mean depth in feet = area of cross-section of pipe, conduit or open channel in square feet ($a$) divided by its wetted perimeter in lineal ft. $r = \frac{a}{p}$

ness.

The plan on which the tables a
ucted will be briefly stated he
ir use will be more fully ex
ther on.

Chezy's general form of formula
ity is—

$$V = c\sqrt{rs} = c\sqrt{r} \times \sqrt{s}$$

refore

$$Q = ac\sqrt{rs} = ac\sqrt{r} \times \sqrt{s}$$

The factors on the right hand
equations are tabulated, $c\sqrt{}$
$\sqrt{r}$ for diameters usually adop
ctice, and $\sqrt{s}$ for 986 slopes.

number representing $\sqrt{s}$ opposite the given slope. The product of these two numbers will give the required velocity. Again, given the slope and velocity in feet per second to find the diameter. From the equation

$$V = c\sqrt{r} \times \sqrt{s}$$

we have

$$c\sqrt{r} = \frac{V}{\sqrt{s}}$$

Look out the value of $\sqrt{s}$ corresponding to the given slope and divide the velocity by it. The quotient will be the value of $c\sqrt{r}$. In the column of $c\sqrt{r}$ look out the nearest number to the value of $c\sqrt{r}$ so found, and opposite to it in the same line will be the diameter required. At the same time the area and hydraulic mean depth can be found on the same line and the discharge can be found by looking out the value of $ac\sqrt{r}$ and dividing it by $\sqrt{s}$. In fact by inspection of the tables and the multiplication or division of two numbers, problems can be rapidly and accurately solved, which, by the use of any one of the formulæ, would be a tedious and troublesome operation. When the value of $c\sqrt{r}$ or $ac\sqrt{r}$ is found, the diameter can at once be found by inspection on the same line.

When the slope and velocity are given and the diameter is required it is not found directly. The value of $c\sqrt{r}$ is first computed by formula (9) and in the same line with this value in the tables will be found the required diameter. In a similar way the slope and discharge being given and the diameter required. The value of $ac\sqrt{r}$ is first computed by formula (14) and in the same line with this value in the tables will be found the required diameter.

The columns of $c\sqrt{r}$ and $ac\sqrt{r}$ can be used to compare velocities and discharges of pipes with equal slopes, and this can be done even when the channels have different degrees of roughness and different diameters.

For instance, a pipe say of 3 feet diameter has a discharge of 20 cubic feet per second by D'Arcy's formula, and it is required to find the diameter of a pipe of similar material which shall discharge 30 cubic feet per second, that is an increase of 50 per cent., the slope being the same in both pipes. Find in Table 1 the value of $ac\sqrt{r}$ opposite 3 feet diameter and it is = 686.76, and this increased by 50 per cent. = 1030.14 = the value of $ac\sqrt{r}$ corresponding to the required diameter. By inspection of Table 1 the nearest value of $ac\sqrt{r}$ greater than this is found to be 1072.6 opposite a diameter of 3 feet 7 inches, which is the required diameter. In a similar manner velocities can be compared by the use of the column giving the values of $c\sqrt{r}$.

For feet measures D'Arcy's formula is

$$V = \left\{ \frac{r s}{.00007726 + \frac{.00000162}{r}} \right\}^{\frac{1}{2}} \qquad (1)$$

and from this we have

$$S = \left( .00007726 + \frac{.00000162}{r} \right) \frac{V^2}{r} \qquad (2)$$

In order to simplify, *substitute for r in feet the diameter d in inches*, and we have

$$S = \left(.00007726 + \frac{.00000162 \times 48}{d}\right)\frac{48\ V^2}{d}$$

$$\therefore S = \left(.00370848\,d + .00373248\right)\frac{V^2}{d^2}$$

As the change will not materially affect the result, Mr. J. B. Francis, C. E., simplifies this into the form

$$S = .00371\left(d+1\right)\frac{V^2}{d^2} \qquad (3)$$

$$\therefore\ V = \left\{\frac{S\,d^2}{.00371(d+1)}\right\}^{\frac{1}{2}} \qquad (4)$$

In order, however, to further simplify the equation into the Chezy form of formula, which is the form required for the preparation and use of the tables adopted by the writer and given in this book, let equation (3) be transformed into one with the *diameter d in feet* and it becomes

$$S = .00371\left(12\,d + 1\right)\frac{V^2}{144\,d^2}$$

$$\therefore\ V = \left\{\frac{144\,d^2\,S}{.00371\ (12\,d+1)}\right\}^{\frac{1}{2}}$$

but $d^2=16\ r^2=16r\times r=4\ d\times r$ substitute this value for $d^2$ in the last equation, and

$$V=\left\{\frac{144\times 4\ d\times r\times S}{.00371\ (12\ d+1)}\right\}^{\frac{1}{2}}$$

therefore, *for feet measures* D'Arcy's formula for velocity is simplified into

$$V=\left(\frac{155256\ d}{12\ d+1}\right)^{\frac{1}{2}}\times\sqrt{rs} \qquad (5)$$

and putting the first factor on the right-hand side of the equation $=c$, we have

$$V=c\ \sqrt{rs}=c\ \sqrt{r}\times\sqrt{s}$$

Kutter's formula for feet measure is

$$V=\left[\frac{41.6+\frac{1.811}{n}+\frac{.00281}{s}}{1+\left(41.6+\frac{.00281}{S}\right)\frac{n}{\sqrt{r}}}\right]\times\sqrt{rs} \quad (6)$$

and putting the first factor on the right-hand side of the equation $=c$ we have

$$V=c\sqrt{r}\times\sqrt{s}$$

Bazin's formula for *open channels* of the *second category* and applicable to channels with an even lining of cut stone, brickwork, or materials with surfaces of equal roughness, exposed to the flow of water, is:

$$V=\sqrt{1\div.0000133\left(4.354+\frac{1}{r}\right)}\times\sqrt{rs} \qquad (7)$$

and putting the first factor under the radical sign, in the right hand side of the equation $= c$ we have:

$$V=c\sqrt{r}\times\sqrt{s} \qquad (8)$$

$$\therefore\ c\sqrt{r}=\frac{V}{\sqrt{s}} \qquad (9)$$

$$\sqrt{s}=\frac{V}{c\sqrt{r}} \qquad (10)$$

$$S=\left(\frac{V}{c\sqrt{r}}\right)^2 \qquad (11)$$

Now

$$Q=a\,V=ac\sqrt{r}\times\sqrt{s} \qquad (12)$$

$$\therefore\ a=\frac{Q}{v} \qquad (13)$$

$$ac\sqrt{r}=\frac{Q}{\sqrt{s}} \qquad (14)$$

$$\sqrt{s}=\frac{Q}{ac\sqrt{r}} \qquad (15)$$

$$s=\left(\frac{Q}{ac\sqrt{r}}\right)^2 \qquad (16)$$

By the use of the tables of factors as applied to the solution of these formulæ all the information relative to pipes, such as velocity, slope, diameter, etc., can be obtained.

In that admirable and useful work, "Molesworth's Pocket Book of Engineering Formulæ," a modified form of Kutter's formula for pipe discharge is given in which the value of

$$C = \frac{181 + \frac{.00281}{s}}{1 + .026\left(41.6 + \frac{.00281}{s}\right)} \qquad (17)$$

For facility of reference I will call this formula Molesworth's Kutter (17).

No mention is made by Molesworth of the value of $n$, that is as to whether the formula is intended to apply to pipes having a *rough* or a *smooth* inner surface. An investigation will, however, show that his formula is accurately applicable to *only one diameter*, that is, to a diameter of one foot and with the value of $n = .013$.

The value of the term $\frac{n}{\sqrt{r}}$ in formula

(6) is given by Molesworth in formula (17) as a *constant* quantity, and = .026, whereas, in fact, it is a variable quantity, its value—with the same value of $n$—changing with every change in the hydraulic mean radius or diameter of pipe.

Now, assuming the value of $n$ taken by Molesworth to be = .013 and substituting this value for $n$ in Kutter's formula (6) we have

$$C = \frac{41.6 + \frac{1.811}{.013} + \frac{.00281}{s}}{1 + \left(41.6 + \frac{.00281}{s}\right)\frac{.013}{\sqrt{r}}}$$

$$\therefore\ c = \frac{181 + \frac{.00281}{s}}{1 + \left(41.6 + \frac{.00281}{s}\right)\frac{.013}{\sqrt{r}}} \qquad (18)$$

but by Molesworth's Kutter (17)

$$\frac{013}{\sqrt{r}} = .026$$

$$\therefore\quad \sqrt{r} = .5$$

$$r = .25$$

and $$d = 1$$

If we substitute in formula (18) for $\sqrt{r}$ its value 0.5, we have:

$$c = \frac{181 + \frac{.00281}{s}}{1 + .026\left(41.6 + \frac{.00281}{s}\right)}$$

which is Molesworth's Kutter (17).

It is therefore apparent that, no matter what the value of $n$ may be, Molesworth's Kutter (17) does not give the same results as Kutter's formula (6), as it gives a constant coefficient of velocity $c$ for all diameters having the same slope and the same value of $n$.

Kutter's formula (6) has certain peculiarities which are wanting in Molesworth's Kutter, and an investigation will show that Molesworth's differs materially from Kutter's formula (6), and that its application, except to one diameter, is sure to lead to serious error. I will briefly explain:

1. By Kutter's formula (6) the value of $c$, or the velocity, changes with every change in the value of $r$, $s$, or $n$, and

with the *same slope* and the same value of $n$, the value of $c$ increases with the increase of $r$, that is with the increase in diameter. It is on this variability of its coefficient to suit the different changes of slope, diameter and lining of channel that the accuracy of Kutter's formula depends. By Molesworth's Kutter a change in the diameter, other things remaining the same, does not affect the value of $c$. With the same slope the value of $c$ is constant for all diameters.

As an instance with a slope of 1 in 1,000:

| | 6 inches diameter. $c =$ | 20 feet diameter. $c =$ |
|---|---|---|
| By Kutter's formula (6). | 69.5 | 146.0 |
| "Molesworth's Kutter (17) | 85.3 | 85 3 |

It will thus be seen that the value of $c$ by Kutter's formula (6), when $s = .001$, has a large range, from 69.5 to 146.0, showing an increase of 111 per cent. from a diameter of 6 inches to a diameter of 20 feet.

It will be further found that Molesworth's formula gives the value of $c$, and therefore the value of the velocity and discharge, too high for diameters less than one foot, and too low for diameters above one foot, and the more the diameter differs from one foot the greater is the error. In these respects it follows the errors of the old formulæ.

2. According to Kutter's formula (6) the value of $c$ increases with the increase of slope for all diameters whose hydraulic mean depth is less than 3.281 feet—one metre—and with a hydraulic mean depth greater than 3.281 feet, an increase of slope gives a diminution in the value of $c$.

The small table, herewith given, shows this:

| | |
|---|---|
| [illegible] | [illegible] |
| tter's formula $c$ =......... | 137.7 |

| | 20 feet dia | |
|---|---|---|
| | 1 in 1,000. | 1 |
| lesworth's Kutter $c$ =... | 85.3 | |
| ter's formula $c$ =......... | 146.0 | |

t will thus be seen that by K
nula (6), when $r = 3$ feet, that i
n 3.281 feet, an increase in the
n 1 in 1,000 to 1 in 40

feet, an increase in the slope from 1 in 1,000 to 1 in 40 causes a greater proportional increase in the coefficient than Kutter gives, and when $r=5$ feet the value of the coefficient does not diminish with the increase of slope, but on the contrary, it increases with the increase in slope, and its value is the same as when $r=3$ feet.

3. By Kutter's formula (6), when the hydraulic mean depth is equal to 3.281 feet, one metre, the value of $c$ is *constant* for all slopes, and is $=\frac{1.811}{n}$, which in this case $=\frac{1.811}{.013}=139.31$.

Let $r=3.281$ feet, and therefore, $\sqrt{r}=\sqrt{3.281}=1.811$, substitute this value in Kutter's formula (6), and we have

$$c=\frac{41.6+\frac{1.811.}{n}+\frac{00.281}{s}}{1+\left(41.6+\frac{.00281}{s}\right)\frac{n}{1.811}}$$

and $\therefore c=\frac{1.811}{n}$ and when $n=.013$

$c=139.31.$

This is the only instance, I believe, where Kutter's formula (6) gives a constant coefficient with a change of slope. By Molesworth's Kutter (17), on the contrary, the value of $c$ changes with every change of slope when $r=3.281$.

It is evident that Molesworth's Kutter was adopted in order to simplify the application of Kutter's formula (6), but its simplification is of no practical use as it gives very inaccurate results.

As shown above, with the exception of its application to one diameter, the formula is not Kutter's, although in appearance bearing a resemblance to it.

However, a modification of Kutter's formula can be made, simpler in form than even Molesworth's Kutter (17), and giving results near enough for all practical purposes to those obtained by the use of the more complicated Kutter formula (6).

The value of $c$ in Kutter's formula (6), with a slope of 1 in 1,000, and $n=.013$, is thus expressed,

$$c=\frac{41.6+\frac{1.811}{.013}+\frac{.00281}{.001}}{1+\left(41.6+\frac{.00281}{.001}\right)\ \frac{.013}{\sqrt{r}}}$$

$$\therefore\ c=\frac{183.72}{1+44.41\times\ \frac{.013}{\sqrt{r}}} \qquad (19)$$

The following table will show the value of the coefficient *c* for several slopes and diameters, according to formulæ (17), (6), and (19):

| | Molesworth Kutter (17) *c*= | Kutter's formula (6) *c*= | Formula (19) *c*= |
|---|---|---|---|
| 6 inch diameter, slope 1 in 40 | 86.9 | 71.5 | 69.5 |
| 6 inch diameter, slope 1 in 1,000 | 85.3 | 69.5 | 69.5 |
| 4 feet diameter, slope 1 in 400 | 87.2 | 117.0 | 116.5 |
| 4 feet diameter, slope 1 in 1.000 | 85.3 | 116.5 | 116.5 |
| 8 feet diameter, slope 1 in 700 | 85.8 | 130.5 | 130.5 |
| 8 feet diameter, slope 1 in 2,600 | 82.9 | 129.8 | 130.5 |

This table shows the close agreement of formula (19) with Kutter's formula (6), and it also shows the inaccurate results obtained by the use of Molesworth's Kutter.

The first column of this table shows that a formula with a *constant* value of $c = 85$, that is:

$$V = 85\sqrt{rs}$$

will give results differing in an extreme case only 2½ per cent. from Molesworth's Kutter, and in the greater number of cases differing only about one per cent.

The second column of the table shows the wide range of the coefficient $c$ by Kutter's formula (6) from 69.5 to 130.5 to suit the different changes in the hydraulic mean depth and slope.

The objection to the old formulæ was that they gave velocities too high for small pipes and channels, and too low for large pipes and channels. The following table will show that the same inaccurate results are obtained by the use of Molesworth's Kutter (17):

| | Velocity in feet per second by | | |
|---|---|---|---|
| | Molesworth (17). | Kutter (6). | Formula 19). |
| 6 inch diameter, slope 1 in 40 | 4.86 | 4.00 | 3.89 |
| 6 inches diameter, slope 1 in 1,000 | 0.95 | 0.78 | 0.78 |
| 4 feet diameter, slope 1 in 400 | 4.36 | 5.85 | 5.83 |
| 4 feet diameter, slope 1 in 1,000 | 2.70 | 3.68 | 3.68 |
| 8 feet diameter, slope 1 in 700 | 4.59 | 6.97 | 6.97 |
| 8 feet diameter, slope 1 in 2,600 | 2.30 | 3.60 | 3.62 |

This table shows that there is a wide difference between the velocities obtained by Molesworth's Kutter (17) and Kutter's formula (6), and it further shows that for the slopes usually adopted in practice for pipes, sewers, conduits, etc., that is for slopes not flatter than 2 feet per mile, or 1 in 2640, formula (19) will give velocities that for all practical purposes may be considered as almost identical with the velocities obtained by Kutter's formula (6).

The tables of factors $c\sqrt{r}$ and $ac\sqrt{r}$ of Kutter in this work are computed by formulæ (19) and the table just given, and also the tables (10) and (11) show how small is the difference in velocity found by the tables of factors and by formula (6). The difference is generally less than one per cent., and it seldom reaches 3 per cent. Further illustrations of the close agreement of these two formulæ will be found further on.

Mr. L. D'A. Jackson, C. E., in his "Hydraulic Manual," and Mr. R. Hering, C.E., in a paper read before the Am. Soc. C. E., in 1878, extend the range of materials to which the different values of $n$ adopted by Kutter apply.

A table of the value of $n$ for different materials compiled from Kutter, Jackson and Hering, is herewith given, and this value of $n$, applies also, in each instance, to the surfaces of other material equally rough.

$n=.009$ well planed timber, in perfect order and alignment; otherwise perhaps .010 would be suitable.

$n=.010$ plaster in pure cement; planed timber; glazed, coated or enameled stoneware and iron pipes; glazed surfaces of every sort in perfect order.

$n=.011$ plaster in cement with one-third sand in good condition; also for iron, cement, and terra cotta pipes, well jointed, and in best order.

$n=.012$ unplaned timber when perfectly continuous on the inside. Flumes.

$n=.013$ ashlar and well-laid brickwork; ordinary metal; earthen and stoneware pipe, in good condition but not new; cement and terra cotta pipe, not well jointed, nor in perfect order; plaster and planed wood in imperfect or inferior condition; and generally the materials mentioned with $n=.010$ when in imperfect or inferior condition.

$n=.015$ second-class or rough-faced brickwork; well-dressed stonework; foul and slightly tuberculated iron; cement and terra cotta pipes, with imperfect joints and in bad order, and canvas lining on wooden frames.

$n=.017$ brickwork, ashlar, and stoneware in an inferior condition; tuberculated iron pipes; rubble in cement or plaster in good order; fine gravel, well rammed, ⅓ to ⅔ inches diameter; and generally the materials mentioned with $n=.013$ when in bad order and condition.

$n=.020$ rubble in cement in an inferior condition; coarse rubble rough-set in a normal condition; coarse rubble set dry; ruined brickwork and masonry; coarse gravel, well rammed, from 1 to 1⅓ inch diameter; canals with beds and banks of very firm, regular gravel, carefully trimmed and punned in defective places; rough rubble with bed partially covered with silt and mud; rectangular wooden troughs with battens on the inside, two inches apart.

$n=.0225$ coarse dry set rubble in bad condition.

$n=.025$ suitable to rivers and canals with earthen beds in perfect order and regimen, and perfectly free from stones and weeds.

$n=.030$ suitable to rivers and canals with earthen beds in moderately good order and regimen, having stones and weeds occasionally.

$n=.035$ suitable for rivers and canals with earthen beds in bad order and regimen, and having stones and weeds in great quantities.

The tables in this book are computed:

1*st.* By D'Arcy's formula (5) for clean pipes flowing under full pressure.

2*d.* By Kutter's formula (19) for pipes, sewers, conduits, etc., flowing full and also for open channels with:

$n = .011$
$n = .012$
$n = .013$ and

3*d.* By the *second type* of Bazin's formula (7) for open channels, applicable to channels with an even lining of cut stone, brickwork, and other materials with surfaces of equal roughness.

The accuracy of the results by Kutter's formula depends on the proper selection of the value of $n$ for the surface of the material over which the water flows.

With reference to the fixing of values of $n$ to some materials Mr. Jackson, in his "Hydraulic Manual," remarks:

"A coefficient of roughness $n = .010$ has been assumed as applicable to glazed or enameled pipes, and one of .013 for ordinary metal or earthenware or stoneware pipes under ordinary conditions, but not new; and there is every reason to believe that these assumptions are generally correct; if we compare the smoothness of surface of a glazed pipe with that of very smooth plaster in cement, and that of an ordinary pipe, in average condition, with that of ashlar or good brickwork; in addition to this, such few partial and limited experimental data as are available, support the assumption."

Again referring to the simplified form of Kutter's formula (19), if we call the numerator on the right hand side of the equation K, for any value of $n$, we have:

$$c=\frac{\mathrm{K}}{1+44.41+\dfrac{n}{\sqrt{r}}}$$

and $$\mathrm{V}=\left\{\frac{\mathrm{K}}{1+\left(44.41\times\dfrac{n}{\sqrt{r}}\right)}\right\}\sqrt{rs} \qquad (20)$$

In the following table the value of K is given for the several values of $n$ already referred to, except those for earthen channels.

| $n=$ | K= | $n=$ | K= |
|---|---|---|---|
| .009 | 245.63 | .015 | 165.14 |
| .010 | 225.51 | .017 | 150.94 |
| .011 | 209.05 | .020 | 134.96 |
| .012 | 195.33 | .0225 | 124.90 |
| .013 | 183.72 | | |

If, therefore, in the application of formula (20), within the limits of $n$, as given in the table, we substitute for $n$ its value, and also the equivalent value of $k$, we have a simplified form of Kutter's formula (6).

For instance, when $n$=.011,

$$V=\left\{\frac{209.05}{1=\left(44.41\times\frac{.011}{\sqrt{r}}\right)}\right\}\times\sqrt{rs}$$

To further simplify formula (20) the value of $\sqrt{r}$ for a large range of diameters will be found in Table 6.

In Table 8 the coefficients of D'Arcy, and Kutter with $n$ = .011 for smooth pipes, are placed in parallel columns for the purpose of comparison. It will be seen that beginning with the small pipes D'Arcy's coefficients have, for the same diameter, a greater value than Kutter's, but that as the diameters increase, the value of the coefficients approach nearer to each other, until at 14 inches diameter they are equal. From this point as the diameters increase, Kutter's coefficients are the greater, the difference increasing with the increased diameter of pipes. For diameters greater than 10 feet D'Arcy's coefficient is almost constant. It increases very little more than 113.5 even for a diameter of 16 feet or more, but Kutter's coefficient continues to increase until such a diameter is reached as is never likely to be required in practice.

Now, the experiments on which D'Arcy's formula is based were made on clean pipes, of the diameters usually adopted in practice, flowing under pressure and under conditions somewhat similar to pipes in actual use, and therefore, as the experiments were conducted with great accuracy, the results are entitled to the confidence of engineers. D'Arcy's experiments did not, however, include pipes of a very large hydraulic mean radius. In one respect he differs from most of the modern authorities, inasmuch as the slope has no effect on the value of the coefficient of his formula.

Mr. J. W. Adams, C. E., in *Engineering News* of March 10th, 1883, writes:

" When the Loch Katrine Water Works for Glasgow were being extended some years since, a portion of the distance was carried over low grounds by a cast-iron trough 6½ feet deep, and 8 feet in width, supported on masonry piers, and giving good opportunity to determine the daily flow. By this and other means, it was found that the cast-iron pipes, 4 feet in diameter, which with a fall of 1 in 1056 on the rest of the line, had been computed to carry 21,000,000 gallons, were really discharging daily 23,430,000 gallons. The engineer, Mr. Gale, brought the matter to Professor Rankine's attention; who, in a paper and subsequent discussion before the Institution of Engineers of Scotland, March 17th, 1869, uses this language: ‘ It might be interesting to the Institution to know that there was a formula which agreed exactly with the results of Mr. Gale’s experiments. Suppose that before these four-feet pipes were laid, the probable discharge had been calculated by D’Arcy’s formula, the result would have differed *by one part in a thousand*, from the actual discharge, which was 23,430,000 gallons daily. This went to show that they now possessed a general formula for the flow of water in pipes, and the resistance to that flow which applied to large as well as to small pipes› it applied to pipes of an inch in diameter, and from Mr. Gale’s experiments they would see that it also applied to pipes four *feet* in diameter.’ The Glasgow pipes had been coated with Dr. Smith’s process, and were treated as clean pipes and calculated by the formula (for clean pipes). I think that D’Arcy’s experiments, conducted as they were under circumstances which contributed in every way to inspire confidence. Mr. Francis' labors in presenting this formula to us in an English dress, with the prestige growing out of his well-known capacity for careful investigation and computation, and Professor Rankine's indorsement of its applicability to all conditions of pipe discharge up to four feet diameter, must be considered as establishing the practical value of *this* special formula for the flow through *iron pipes.*"

Further on it will be shown, when explaining the use of the tables, that the velocity in the Loch Katrine pipes, found readily by the use of the tables, agrees exactly with the actual velocity, and also with the velocity by D'Arcy's formula.

M. W. Humber, C. E., in his work on "Water Supply," states:

"That which is known as D'Arcy's formula, in pipes of large diameter appears to approach in its results nearer to the actual discharge than any other, and it was the opinion of Professor Rankine, that the resistance decreases to a greater extent in pipes of larger diameter than has been previously supposed. The experiments were made with, and the formula of D'Arcy deduced from, pipes which had been long in use without offering any impediments from incrustation."

Kutter's formula is derived not only from experiments made on channels with small hydraulic radius, but also on channels with large hydraulic radius, and his coefficients for very large pipes are therefore more likely to agree with the actual discharge than D'Arcy's constant coefficient of 113.5 for very large pipes. But, again, Kutter's formula is open to the objection that it is based on experiments made on open channels. I may here remark, although it is only remotely connected with pipe discharge, that Major Allan Cunningham states, as the result of his extensive experiments for four years on the Ganges Canal, that Kutter's formula alone, of all those tried by him, was found generally applicable to all conditions of discharge, and that it gave nearer results to the actual velocity than any of the other formulæ tried by him. It gave results with a difference from the actual velocity seldom exceeding 7½ per cent., and usually much less than that. When we contrast the wide divergence of the old formulæ under varying flow from the actual velocity, with the results obtained by Kutter's formula, it will be seen that the latter is the most accurate formula for channels with large hydraulic mean radius.

In Tables 2, 3, and 4, the values of the factors of Kutter's formula are not given for diameters less than 5 inches. Mr. L. D'A. Jackson, C. E., in his *Hydraulic Manual*, states:

"For the present, and until further experiments have thrown more light on the subject, it may be assumed that the coefficient of discharge for all full cylindrical pipes, having a diameter less than 0.4 feet, will be the same as those of that diameter."

Although Mr. Jackson's opinion is entitled to great weight, still the facts all tend to prove that the coefficients of diameters below 5 inches should diminish with the diminution of diameter. The smaller the diameter the more effect will the roughness of the surface have in diminishing the discharge. Table 9 shows that Kutter's coefficient for 5 inches diameter with $n = .011$ is 82.9, and therefore, according to Mr. Jackson, all the diameters from 5 inches to ⅜ inch should have a coefficient of 82.9. This is contrary to the principle of Kutter's formula, the accuracy of which is due to the fact that, other things being equal, its coefficients vary with the diameter. The following proofs are given in support of the opinion that coefficients of diameters below 5 inches should diminish according to the diminution of diameter.

1. In Table 9 the coefficients of D'Arcy's formula are seen to diminish with the diminution of diameter. At 5 inches diameter the coefficient is 103.8, and at ⅜ inch diameter 59.4.

2. In Table 9 the coefficients of Fanning's formula diminish from 4 inches diameter with a coefficient of 103.4 to

one inch diameter with a coefficient of 80.4.

These coefficients are derived from the mean velocities in clean pipes with a slope of 1 in 125 given in Fanning's tables.

3. In Table 9 the coefficients, as found by Kutter's formula with a slope of 1 in 1,000, and $n = .011$, are for 5 inches diameter, 82.9, and for ⅜ inch diameter, 32.0.

The facts, therefore, show that the coefficients diminish from a diameter of 5 inches to smaller diameters, and it is a safer plan to adopt coefficients varying with the diameter than a constant coefficient. No opinion is advanced as to what coefficients should be used with Kutter's formula for small diameters. The facts are simply stated, giving the results of well-known authors.

As the coefficients of D'Arcy's formula vary only with the diameter, the values of the factors $c\sqrt{r}$ and $ac\sqrt{r}$, given in Table 1 for D'Arcy's formula are practically the exact values for all diameters and slopes given, and the results found by the use of the tables will be the same as the results found by using the formula.

In Tables 2, 3, and 4, the values of $c\sqrt{r}$ and $ac\sqrt{r}$ for Kutter's formula sometimes differ by a small quantity from the actual values as found by the use of formula (6). These values by Kutter's formula depend not only on $r$, but also on $n$ and $s$, so that a change in any of these three quantities causes a change in the values of $c\sqrt{r}$ and $ac\sqrt{r}$. It is found, however, that the slope of 1 in 1,000 will give coefficients which practically differ very little from the coefficients derived from the slopes usually given to lines of pipe.

The values of the coefficients from Kutter's formula given in the tables have been computed for a slope of 1 in 1,000, and they give values of $c\sqrt{r}$ and $ac\sqrt{r}$ near enough for practical work.

I will here give another instance of the correctness of the tables. In a late report on the Sewerage of Washington, D. C., by Captain F. V. Greene, U. S. Engineers, a table is given of the discharge of several egg-shaped and also two circular sewers of brickwork computed by Kutter's formula (6) with $n=.013$.

The small table, now given, shows the discharge of the circular sewers as taken from Captain Greene's report, and also the discharge as computed by the tables in this work.

| | Discharge in cubic feet per second. | |
|---|---|---|
| | By Capt. Greene's Report. | By the Tables in this Work. |
| 10 feet diameter, slope 1 in 100 | 1673.66 | 1670.90 |
| 10 feet diameter, slope 1 in 200 | 1183.28 | 1181.49 |
| 10 feet diameter, slope 1 in 300 | 965.70 | 964.69 |
| 20 feet diameter, slope 1 in 100 | 10240.64 | 10255.90 |
| 20 feet diameter, slope 1 in 200 | 7240.13 | 7251.95 |
| 20 feet diameter, slope 1 in 300 | 5908.85 | 5921.24 |

The difference in discharge is so very small that the results as given by the rapid method of the tables may, for all practical purposes, be taken as identical to those given by the use of the troublesome and tedious formula (6).

Should the engineer, however, prefer to use formula (6), even then the tables will give a ready means of checking the computations.

## EXPLANATION AND USE OF THE TABLES.

The velocity mentioned below means velocity in feet per second. The discharge mentioned below means the discharge in cubic feet per second.

*Example* 1. What is the velocity and discharge by Kutter's formula of an iron pipe of 2 feet diameter, and with a fall of 9 feet per mile, the value of $n$ being assumed equal to .013.

By formula (8) $V=c\sqrt{r}\times\sqrt{s}$

and by formula (12) $Q=ac\sqrt{r}\times\sqrt{s}$

In Table 7 look out the value of $\sqrt{s}$ corresponding to a fall of 9 feet per mile, and it is found $=.041286$. Look out also in Table 4 the value of $c\sqrt{r}$ and $ac\sqrt{r}$ opposite a diameter of 2 feet, and they will be found to be respectively equal to 71.49 and 224.63—substituting the values so found in equations (8) and (12), and we have

$V = 71.49 \times .041286 = 2.95$ feet per second velocity.

$Q = 224.63 \times .041286 = 9.27$ c. feet per second discharge.

If the velocity and discharge are found by Kutter's formula (6) it will be seen that a very great saving of work is effected by the use of the tables.

*Example* 2. An open channel constructed of brick masonry, rectangular in cross section, four feet wide on bottom and with vertical sides, carries two feet in depth of water and has a slope of 1 in 160. What is its velocity and discharge by Bazin's formula for open channels? As the channel is of brickwork it comes under the head of the second type of Bazin's formula for open channels by which Table 5 is constructed. The hydraulic mean depth $r = \frac{\text{area}}{\text{wetted perimeter}} = {}^8/_8 = 1$. In Table 5 we find that when $r = 1$ the value of $c\sqrt{r} = 118.5$. We also find in Table 7 that the $\sqrt{s}$ corresponding to a slope of 1 in $160 = .079057$, substitute these values in formula (S) and $V = 118.5 \times .079057 = 9.37$ feet per second and $Q = aV = 8 \times 9.37 = 74.96$ cubic feet per second.

*Example* 3. An iron pipe one foot six inches in diameter, whose natural coefficient of roughness is assumed $= .011$, is to have a velocity not to exceed 3 feet per second. What should its slope be by the use of Kutter's formula?

By formula (10)

$$\sqrt{s} = \frac{V}{c\sqrt{r}}$$

Find by inspection in Table 2 the value of $c\sqrt{r}$ opposite 1 foot 6 inches. It is equal to 7.108. Substitute this value and also the given velocity in equation (11) and we have

$$\sqrt{s} = \frac{3}{71.08} = .042206$$

Look out the nearest value of $\sqrt{s}$ to this in Table 7, and it will be found to be .043519 opposite a slope of 10 feet per mile, which is the slope required.

*Example* 4. A 3 feet 6 inch old iron pipe whose natural coefficient is assumed

=.013 is to be replaced by a new pipe capable of discharging double that of the old pipe, the slope remaining unchanged. What is the diameter by Kutter's formula of the new pipe, its natural coefficient being assumed = .011.

Find by inspection in Table 4 the value of $ac\sqrt{r}$ opposite 3 feet 6 inches diameter. It is found equal to 1021.1. Then 1021.1 $\times 2 = 2042.2$. As the value of $n$ for the new pipe = .011, look out in Table 2 the value of $ac\sqrt{r}$ nearest to 2042.2, and it is found to be 2072.7 opposite a diameter of 4 feet 3 inches, which is the diameter required.

Look up the values of $c\sqrt{r}$ for each pipe, and it will be seen that the velocity in the new pipe is to that in the old as 146:106.

*Example.* 5. Find by Kutter's formula the slope of a flume, constructed of unplaned planks, 5 feet wide on bottom and with vertical sides 2½ feet high, in order that it may discharge 102 cubic feet per second.

In Table 3 when $r=1.25$,
ing value of $c\sqrt{r}=147.9$

$$V=\frac{Q}{a}=\frac{102}{12.5}=8.16\text{ f}$$

substitute these values of
formula (10), and we have:

$$\sqrt{s}=\frac{8.16}{147.9}=.0551$$

Now look out in Table
value of $\sqrt{s}$ to this, and we
opposite a slope of 1 in 330
slope required.

*Example* 6. This example
Weisbach's *Mechanics of E*

A system of pipes cons

feet in 600, and the other branch 1 foot in 200. What diameter should the pipes have?

For the solution of this example table 1, derived from D'Arcy's formula, will be used.

The main is to discharge 39 cubic feet per minute, equal to 0.65 cubic feet per second with a slope of 1 in 250. One branch 15 cubic feet per minute, equal to 0.25 cubic feet per second, with a fall of 1 in 200, and the other branch, 24 cubic feet per minute = 0.4 cubic feet per second, with a fall of 1 in 200.

By inspection find in Table 7 the value of $\sqrt{s}$ nearest to 1 in 250 (21 feet per mile) and it is found to be = .063066, and also find the value of $\sqrt{s}$ nearest to 1 in 200 (26 feet per mile). It is found = .070173. By formula (14).

$$ac\sqrt{r} = \frac{Q}{\sqrt{s}}$$

$\therefore$ for main pipe $ac\sqrt{r} = \frac{0.65}{.063066} = 10.307$

the nearest value of $ac\sqrt{r}$ to this in Table

1 is 10.852, opposite which is the diameter, 7 inches.

In the same manner for the first branch,

$$ac\sqrt{r} = \frac{0.25}{.070173} = 3.562$$

and the nearest value of $ac\sqrt{r}$ to this, in Table 1, is 4.561, corresponding to a diameter of 5 inches.

For the second branch,

$$ac\sqrt{r} = \frac{0.4}{.070173} = 5.7$$

and the nearest value of $ac\sqrt{r}$ to this, in Table 1, is 7.3 opposite a diameter of 6 inches. The required diameters are therefore: for the main pipe 7 inches, for the first branch 5 inches, and for the second branch 6 inches.

Although the explanation of this example, in the use of the tables may appear somewhat long, still the actual work can be done very rapidly and with little trouble. If a comparison is made of the work required for the solution of this example, as given above by the tables, with the work required for its solution by the method of approximation as given in Weisbach's *Mechanics of Engineering*, from which the example is extracted, it will be seen that there is a great saving of labor effected by the use of the tables.

*Example* 7. Humber, in his work on *Water Supply*, states:

"With a 48-inch cast-iron pipe in the Loch Katrine Water Works, having an inclination of 1 in 1056, or 5 feet per mile, the actual velocity was found to be 3.46 feet per second, and D'Arcy's formula gives practically the same results."

Let us now find the velocity in this pipe by the tables. A 48-inch pipe has a hydraulic mean depth $r$ of one foot.

In Table 1, computed from D'Arcy's formula for clean pipes, we find the value of $r = 1$, and in the same line we find the value of $c\sqrt{r} = 112.6$.

We also find in Table 7 that $\sqrt{s}$ for a slope of 1 in 1056 $= .030773$. Subtsitute these values in the formula (8).

$V = c\sqrt{r} \times \sqrt{s}$, and we have
$V = 112.6 \times 030773 = 3.46$ feet per second, being exactly the same as the actual velocity, and also the same as the velocity found by the use of D'Arcy's formula.

*Example* 8. Near the head of a small irrigation canal the supply of water is carried in a rock cutting 10 feet wide at bottom; 12 feet wide at surface of water; 5 feet in depth and having a slope of 1 in 880.

The water supply carried in this cutting being insufficient it is determined to increase the supply, without, however, increasing the cross-sectional area of channel or its slope. The bottom and sides of the rock cutting are very rough, and in order to give them a smoother surface and increase the discharge, it is determined to fill up all the hollows in them with masonry, and after this to lay on carefully a coat of cement plaster with one-third sand, and to make the surfaces in contact with the water smooth and even.

After the plastering is finished the dimensions of the channel will be: width at bottom 9.8 feet: width at water surface 11.8 feet: depth of water 4.9 feet and the slope as before, 1 in 880.

It is assumed that a near approximation to the value of $n$ for the rock cutting $=.0225$ and for the plastered channel $n=.011$.

Find the increase in discharge in the plastered channel over that in the original channel.

In the original channel

$$r=\frac{\text{area}}{\text{wetted perimeter}}=\frac{55}{20.2}=2.7228$$

For a slope of 1 in 880, Table 7 gives $S=.001136$ $N=.0225$.

Substitute these values of $r$, $s$ and $n$ in formula (6) and we have:

$$V=\frac{41.6+\frac{1.811}{.0225}+\frac{.00281}{.001136}}{1+\left(41.6\frac{.00281}{.001136}\right)\frac{.0225}{\sqrt{2.7228}}}\times\sqrt{2.7228\times.001136}$$

$\therefore$ $V=4.327$ feet per second.

Now $Q=Va=4.327\times55=238$ cubic feet per second.

In the *plastered channel:*

$$r = \frac{\text{area}}{\text{wetted perimeter}} = \frac{52.92}{19.8} = 2.673.$$

In Table 2 with $n = .011$ there is no value of $r$ equal to 2.673, but the value of $r$ immediately more than it, 2.687 has a value of $c\sqrt{r} = 264.0$, and the value of $r$ less than it, 2.625 has $c\sqrt{r} = 260.2$. From these when $r = 2.673$ the value of $c\sqrt{r} = 263.15$.

In Table 7 for a slope of 1 in 880 the value of $\sqrt{s} = .03371$.

Substitute these values of $r$ and $s$ in formula (8), and

$$V = c\sqrt{r} \times \sqrt{s}, \text{ and}$$

$V = 263.15 \times .03371 = 8.87$ feet per second, and

$Q = Va = 8.87 \times 52.92 = 469.4$ cubic feet per second.

We here see the effect of a smooth surface in increasing the velocity and discharge of a channel. Although the cross-sectional area has been *diminished,* still the effect of giving a smooth surface to the channel has been to *more than* *double its velocity* and to *almost double the discharge.* The old formula would give almost the same velocity and discharge to the two channels, as these formulæ do not take the surfaces exposed to the flow of water into account.

*Example* 9. A canal with an earthen bed in moderately good order is to have a bottom width of 52 feet; depth of water 6 feet; side slopes 1½ to 1, and a slope of one foot per mile. What is its velocity and discharge by Kutter's formula?

The value of $n$ for this channel may be assumed as equal to 0.3 The value of $s$ for a fall of one foot per mile will be found in Table 7 =.00018939.

$$r=\frac{\text{area}}{\text{wetted perimeter}}=\frac{366}{73.64}=4.97$$

Substitute the above values of $n$, $r$ and $s$ in formula (6) and

$$V=\frac{41.6+\frac{1.811}{.03}+\frac{.00281}{.00018939}}{1+\left(41.6+\frac{.00281}{.00018939}\right)\frac{.03}{\sqrt{4.97}}}\times\sqrt{\begin{matrix}\times 4.97\\ .000318939\end{matrix}}$$

$\therefore$ V=2.037 feet per second, and

$Q=Va=2.037\times366=745$ cubic feet per second.

Therefore the velocity=2 feet per second and the discharge 745 cubic feet per second.

No. 67 of "Van Nostrand's Science Series," by the author, and entitled, "Hydraulic Tables, based on Kutter's formula," contains an extensive table of slopes and $\sqrt{s}$ from 1 in 4 to 1 in 1,000, and also tables of factors for circular and egg-shaped brick sewers with $n=.015$.

## TABLE 1.—Circular Pipes, Sewers, Conduits, etc., flowing under pressure.

D'Arcy's formula for clean pipes.

Table giving the values of $a$ and $r$, and also the values of the factors $c\sqrt{r}$ and $ac\sqrt{r}$ for use in the formulæ.

$V=c\sqrt{r} \times \sqrt{s}$  $Q=ac\sqrt{r} \times \sqrt{s}$

These factors are to be used only for clean pipes under pressure.

| $d$=diameter in | | $a$=area in square feet. | $r$=hydraulic mean depth in feet. | For velocity $c\sqrt{r}$. | For discharge $ac\sqrt{r}$. |
|---|---|---|---|---|---|
| ft. | ins. | | | | |
| 0 | ⅜ | .00077 | .0078 | 5.251 | .00403 |
| 0 | ½ | .00136 | .0104 | 6.702 | .00914 |
| 0 | ¾ | .00307 | .0156 | 9.309 | .02855 |
| 0 | 1 | .00545 | .0208 | 11.61 | .06334 |
| 0 | 1¼ | .00852 | .0260 | 13.68 | .11659 |
| 0 | 1½ | .01227 | .0312 | 15.58 | .19115 |
| 0 | 1¾ | .01670 | .0364 | 17.32 | .28936 |
| 0 | 2 | .02182 | .0417 | 18.96 | .41357 |
| 0 | 2½ | 0.0341 | 0.052 | 21.94 | .74786 |
| 0 | 3 | 0.0491 | 0.063 | 24.63 | 1.2089 |
| 0 | 4 | 0.0873 | 0.084 | 29.37 | 2.5630 |
| 0 | 5 | 0.136 | 0.104 | 33.54 | 4.5610 |
| 0 | 6 | 0.196 | 0.125 | 37.28 | 7.3068 |

## Table 1.—D'Arcy's formula for clean pipes.

| $d$=diameter in f. | ins. | $a$=area in square feet. | $r$=hydraulic mean depth in feet. | For velocity $c\sqrt{r}$. | For discharge $ac\sqrt{r}$. |
|---|---|---|---|---|---|
| 0 | 7 | 0.267 | 0.146 | 40.65 | 10.852 |
| 0 | 8 | 0.349 | 0.167 | 48.75 | 15.270 |
| 0 | 9 | 0.442 | 0.187 | 46.73 | 20.652 |
| 0 | 10 | 0.545 | 0.208 | 49.45 | 26.952 |
| 0 | 11 | 0.660 | 0.229 | 52.16 | 34.428 |
| 1 | 0 | 0.785 | 0.250 | 54.65 | 42.918 |
| 1 | 1 | 0.922 | 0.271 | 57.00 | 52.551 |
| 1 | 2 | 1.069 | 0.292 | 59.34 | 63.435 |
| 1 | 3 | 1.227 | 0.313 | 61.56 | 75.537 |
| 1 | 4 | 1.396 | 0.333 | 63.67 | 88.886 |
| 1 | 5 | 1.576 | 0.354 | 65.77 | 103.66 |
| 1 | 6 | 1.767 | 0.375 | 67.75 | 119.72 |
| 1 | 7 | 1.969 | 0.396 | 69.74 | 137.31 |
| 1 | 8 | 2.182 | 0.417 | 71.71 | 156.46 |
| 1 | 9 | 2.405 | 0.437 | 73.46 | 176.66 |
| 1 | 10 | 2.640 | 0.458 | 75.32 | 198.83 |
| 1 | 11 | 2.885 | 0.479 | 77.05 | 222.30 |
| 2 | 0 | 3.142 | 0.500 | 78.80 | 247.57 |
| 2 | 1 | 3.409 | 0.521 | 80.53 | 274.53 |
| 2 | 2 | 3.687 | 0.542 | 82.15 | 302.90 |
| 2 | 3 | 3.976 | 0.562 | 83.77 | 333.07 |
| 2 | 4 | 4.276 | 0.583 | 85.39 | 365.14 |
| 2 | 5 | 4.587 | 0.604 | 86.89 | 398.57 |
| 2 | 6 | 4.909 | 0.625 | 88.39 | 433.92 |
| 2 | 7 | 5.241 | 0.646 | 90.01 | 471.73 |
| 2 | 8 | 5.585 | 0.667 | 91.51 | 511.10 |
| 2 | 9 | 5.939 | 0.687 | 92.90 | 551.72 |

TABLE 1.—D'Arcy's formula for clean pipes.

| $d$=diameter in | | $a$=area in square feet. | $r$=hydraulic mean depth in feet. | For velocity $c\sqrt{r}$. | For discharge $ac\sqrt{r}$. |
|---|---|---|---|---|---|
| ft. | ins. | | | | |
| 2 | 10 | 6.305 | 0.708 | 94.40 | 595.17 |
| 2 | 11 | 6.681 | 0.729 | 95.78 | 639.88 |
| 3 | 0 | 7.068 | 0.750 | 97.17 | 686.76 |
| 3 | 1 | 7.466 | 0.771 | 98.55 | 735.75 |
| 3 | 2 | 7.875 | 0.792 | 99.93 | 786.94 |
| 3 | 3 | 8.295 | 0.812 | 101.2 | 839.38 |
| 3 | 4 | 8.726 | 0.833 | 102.6 | 895.07 |
| 3 | 5 | 9.169 | 0.854 | 103.8 | 952.10 |
| 3 | 6 | 9.621 | 0.875 | 105.1 | 1011.2 |
| 3 | 7 | 10.084 | 0.896 | 106.4 | 1072.6 |
| 3 | 8 | 10.559 | 0.917 | 107.6 | 1136.5 |
| 3 | 9 | 11.044 | 0.937 | 108.9 | 1202.7 |
| 3 | 10 | 11.541 | 0.958 | 110.2 | 1271.4 |
| 3 | 11 | 12.048 | 0.979 | 111.4 | 1342.4 |
| 4 | 0 | 12.566 | 1.000 | 112.6 | 1414.7 |
| 4 | 1 | 13.096 | 1.021 | 113.7 | 1489.4 |
| 4 | 2 | 13.635 | 1.042 | 115.0 | 1567.8 |
| 4 | 3 | 14.186 | 1.062 | 116.1 | 1647.6 |
| 4 | 4 | 14.748 | 1.083 | 117.3 | 1729.8 |
| 4 | 5 | 15.321 | 1.104 | 118.4 | 1814.6 |
| 4 | 6 | 15.904 | 1.125 | 119.6 | 1901.9 |
| 4 | 7 | 16.499 | 1.146 | 120.6 | 1990.1 |
| 4 | 8 | 17.104 | 1.167 | 121.8 | 2082.6 |
| 4 | 9 | 17.721 | 1.187 | 122.8 | 2176.1 |
| 4 | 10 | 18.348 | 1.208 | 124.0 | 2274.1 |
| 4 | 11 | 18.986 | 1.229 | 125.1 | 2374.8 |
| 5 | 0 | 19.635 | 1.250 | 126.1 | 2476.4 |

TABLE 1.—D'Arcy's formula for clean pipes.

| $d$=diameter in |  | $a$=area in square feet. | $r$=hydraulic mean depth in feet. | For velocity $c\sqrt{r}$. | For discharge $ac\sqrt{r}$. |
|---|---|---|---|---|---|
| ft. | ins. |  |  |  |  |
| 5 | 1 | 20.295 | 1.271 | 127.2 | 2580.5 |
| 5 | 2 | 20.966 | 1.292 | 128.3 | 2689.9 |
| 5 | 3 | 21.648 | 1.312 | 129.3 | 2799.7 |
| 5 | 4 | 22.340 | 1.333 | 130.4 | 2912.4 |
| 5 | 5 | 23.044 | 1.354 | 131.4 | 3027.8 |
| 5 | 6 | 23.758 | 1.375 | 132.4 | 3146.3 |
| 5 | 7 | 24.484 | 1.396 | 133.4 | 3264.9 |
| 5 | 8 | 25.220 | 1.417 | 134.4 | 3388.9 |
| 5 | 9 | 25 967 | 1.437 | 135.4 | 3516.0 |
| 5 | 10 | 26.725 | 1.558 | 136.4 | 3646.1 |
| 5 | 11 | 27.494 | 1.479 | 137.4 | 3776.2 |
| 6 | 0 | 28.274 | 1.500 | 138.4 | 3912.8 |
| 6 | 3 | 30.680 | 1.562 | 141.3 | 4333.6 |
| 6 | 6 | 33.183 | 1.625 | 144.1 | 4782.1 |
| 6 | 9 | 35.785 | 1.687 | 146.9 | 5255.1 |
| 7 | 0 | 38.485 | 1.750 | 149.6 | 5757.5 |
| 7 | 3 | 41.283 | 1.812 | 152.2 | 6284.6 |
| 7 | 6 | 44.179 | 1.879 | 154.9 | 6841.6 |
| 7 | 9 | 47.173 | 1.937 | 157.5 | 7429.3 |
| 8 | 0 | 50.266 | 2.000 | 160.0 | 8043.0 |
| 8 | 3 | 53.456 | 2.062 | 162.5 | 8688.0 |
| 8 | 6 | 56.745 | 2.125 | 165.0 | 9364.7 |
| 8 | 9 | 60.132 | 2.187 | 167.4 | 10068. |
| 9 | 0 | 63.617 | 2.250 | 169.8 | 10804. |
| 9 | 3 | 67.201 | 2.312 | 172.2 | 11575. |
| 9 | 6 | 70.882 | 2.375 | 174.5 | 12370. |
| 9 | 9 | 74.662 | 2.437 | 176.8 | 13200. |

**Table 1.—D'Arcy's formula for clean pipes.**

| $d$=diameter in ft. | ins. | $a$=area in square feet. | $r$=hydraulic mean depth in feet. | For velocity $c\sqrt{r}$. | For discharge $ac\sqrt{r}$. |
|---|---|---|---|---|---|
| 10 | 0 | 78.540 | 2.500 | 179.1 | 14066. |
| 10 | 3 | 82.516 | 2.562 | 181.4 | 14967. |
| 10 | 6 | 86.590 | 2.625 | 183.6 | 15893. |
| 10 | 9 | 90.763 | 2.687 | 185.7 | 16856. |
| 11 | 0 | 95.033 | 2.750 | 187.9 | 17855. |
| 11 | 3 | 99.402 | 2.812 | 190.1 | 18892. |
| 11 | 6 | 103.869 | 2.875 | 192.2 | 19966. |
| 11 | 9 | 108.434 | 2.937 | 194.3 | 21065. |
| 12 | 0 | 113.098 | 3.000 | 196.3 | 22204. |
| 12 | 3 | 117.859 | 3.062 | 198.4 | 23379. |
| 12 | 6 | 122.719 | 3.125 | 200.4 | 24598. |
| 12 | 9 | 127.677 | 3.187 | 202.4 | 25840. |
| 13 | 0 | 132.733 | 3.250 | 204.4 | 27134. |
| 13 | 3 | 137.887 | 3.312 | 206.4 | 28456. |
| 13 | 6 | 143.139 | 3.375 | 208.3 | 29818. |
| 13 | 9 | 148.490 | 3.437 | 210.2 | 31219. |
| 14 | 0 | 153.938 | 3.500 | 212.2 | 32664. |
| 14 | 6 | 165.130 | 3.625 | 216.0 | 35660. |
| 15 | 0 | 176.715 | 3.750 | 219.6 | 38807. |
| 15 | 6 | 188.692 | 3.875 | 223.3 | 42125. |
| 16 | 0 | 201.062 | 4.000 | 226.9 | 45621. |
| 16 | 6 | 213.825 | 4.125 | 230.4 | 49273. |
| 17 | 0 | 226.981 | 4.250 | 233.9 | 53082. |
| 17 | 6 | 240.529 | 4.375 | 237.3 | 57074. |
| 18 | 0 | 254.470 | 4.500 | 240.7 | 61249. |
| 19 | 0 | 283.529 | 4.750 | 247.4 | 70154. |
| 20 | 0 | 314.159 | 5.000 | 253.8 | 79736. |

TABLE 2.—Circular Pipes, Sewers, Conduits, etc., flowing full. Kutter's formula with $n=.011$.

Table giving the values of $a$ and $r$ and also the values of the factors $c\sqrt{r}$ and $ac\sqrt{r}$ for use in the formulæ,

$$V=c\sqrt{r} \times \sqrt{s} \qquad Q=ac\sqrt{r} \times \sqrt{s}$$

These factors are to be used only where the value of $n$, that is the coefficient of roughness of lining of channel, $=.011$, as for surfaces carefully plastered with cement with one-third sand in good condition, also for iron, cement and terra-cotta pipes, well jointed and in best order, and also surfaces of other material equally rough.

| $d$=diameter in ft. | ins. | $a$=area in square feet. | $r$=hydraulic mean depth in feet. | For velocity $c\sqrt{r}$. | For discharge $ac\sqrt{r}$. |
|---|---|---|---|---|---|
| 0 | 5 | 0.136 | 0.104 | 26.76 | 3.6398 |
| 0 | 6 | 0.196 | 0.125 | 30.98 | 6.0627 |
| 0 | 7 | 0.267 | 0.146 | 34.94 | 9.3294 |
| 0 | 8 | 0.349 | 0.167 | 38.77 | 13.531 |
| 0 | 9 | 0.442 | 0.187 | 42.40 | 18.742 |

TABLE 2.—Kutter's formula with $n$=.011.

| $d$=diameter in ft. | $d$=diameter in ins. | $a$=area in square feet. | $r$=hydraulic mean depth in feet. | For velocity $c\sqrt{r}$. | For discharge $ac\sqrt{r}$. |
|---|---|---|---|---|---|
| 0 | 10 | 0.545 | 0.208 | 45.83 | 24.976 |
| 0 | 11 | 0.660 | 0.229 | 49.46 | 32.644 |
| 1 | 0 | 0.785 | 0.250 | 52.85 | 41.487 |
| 1 | 1 | 0.922 | 0.271 | 55.95 | 51.588 |
| 1 | 2 | 1.069 | 0.292 | 59.13 | 63.210 |
| 1 | 3 | 1.227 | 0.312 | 62.22 | 76.347 |
| 1 | 4 | 1.396 | 0.333 | 65.21 | 91.037 |
| 1 | 5 | 1.576 | 0.354 | 68.26 | 107.58 |
| 1 | 6 | 1.767 | 0.375 | 71.08 | 125.60 |
| 1 | 7 | 1.969 | 0.396 | 73.90 | 145.51 |
| 1 | 8 | 2.182 | 0.417 | 76.75 | 167.50 |
| 1 | 9 | 2.405 | 0.437 | 79.33 | 190.79 |
| 1 | 10 | 2.640 | 0.458 | 82.11 | 216.76 |
| 1 | 11 | 2.885 | 0.479 | 84.75 | 244.50 |
| 2 | 0 | 3.142 | 0.500 | 87.36 | 274.50 |
| 2 | 1 | 3.409 | 0.521 | 89.94 | 306.60 |
| 2 | 2 | 3.687 | 0.542 | 92.38 | 340.59 |
| 2 | 3 | 3.976 | 0.562 | 94.84 | 377.07 |
| 2 | 4 | 4.276 | 0.583 | 97.33 | 416.16 |
| 2 | 5 | 4.587 | 0.604 | 99.66 | 457.13 |
| 2 | 6 | 4.909 | 0.625 | 102.0 | 500.78 |
| 2 | 7 | 5.241 | 0.646 | 104.5 | 547.92 |
| 2 | 8 | 5.585 | 0.667 | 106.8 | 596.70 |
| 2 | 9 | 5.939 | 0.687 | 109.0 | 647.18 |
| 2 | 10 | 6.305 | 0.708 | 111.3 | 701.77 |
| 2 | 11 | 6.681 | 0.729 | 113.5 | 758.16 |
| 3 | 0 | 7.068 | 0.750 | 115.7 | 817.50 |

## TABLE 2.—Kutter's formula with $n$=.011.

| $d$=diameter in | | $a$=area in square feet. | $r$=hydraulic mean depth in feet. | For velocity $c\sqrt{r}$. | For discharge $ac\sqrt{r}$. |
|---|---|---|---|---|---|
| ft. | ins. | | | | |
| 3 | 1 | 7.466 | 0.771 | 117.9 | 880.03 |
| 3 | 2 | 7.875 | 0.792 | 120.1 | 945.69 |
| 3 | 3 | 8.295 | 0.812 | 122.1 | 1013.1 |
| 3 | 4 | 8.723 | 0.833 | 124.3 | 1084.6 |
| 3 | 5 | 9.169 | 0.854 | 126.3 | 1158.0 |
| 3 | 6 | 9.621 | 0.875 | 128.3 | 1234.4 |
| 3 | 7 | 10.084 | 0.896 | 130.3 | 1314.1 |
| 3 | 8 | 10.559 | 0.917 | 132.3 | 1397.1 |
| 3 | 9 | 11.044 | 0.937 | 134.4 | 1484.2 |
| 3 | 10 | 11.541 | 0.958 | 136.4 | 1574.7 |
| 3 | 11 | 12.048 | 0.979 | 138.3 | 1666.5 |
| 4 | 0 | 12.566 | 1.000 | 140.4 | 1764.3 |
| 4 | 1 | 13.096 | 1.021 | 142.2 | 1862.7 |
| 4 | 2 | 13.635 | 1.042 | 144.3 | 1967.1 |
| 4 | 3 | 14.186 | 1.062 | 146.1 | 2072.7 |
| 4 | 4 | 14.748 | 1.083 | 148.0 | 2182.5 |
| 4 | 5 | 15.321 | 1.104 | 149.9 | 2296.0 |
| 4 | 6 | 15.904 | 1.125 | 151.7 | 2413.3 |
| 4 | 7 | 16.499 | 1.146 | 153.4 | 2531.7 |
| 4 | 8 | 17.104 | 1.167 | 155.3 | 2657.1 |
| 4 | 9 | 17.721 | 1.187 | 157.1 | 2783.4 |
| 4 | 10 | 18.348 | 1.208 | 159.0 | 2917.0 |
| 4 | 11 | 18.986 | 1.229 | 160.9 | 3054.1 |
| 5 | 0 | 19.635 | 1.250 | 162.6 | 3191.8 |
| 5 | 1 | 20.295 | 1.271 | 164.5 | 3337.5 |
| 5 | 2 | 20.966 | 1.292 | 166.0 | 3480.8 |
| 5 | 3 | 21.648 | 1.312 | 167.9 | 3634.2 |

TABLE 2.—Kutter's formula with $n=.011$.

| $d$=diameter in ft. | ins. | $a$=area in square feet. | $r$=hydraulic mean depth in feet. | For velocity $c\sqrt{r}$. | For discharge $ac\sqrt{r}$. |
|---|---|---|---|---|---|
| 5 | 4 | 22.340 | 1.333 | 169.6 | 3789.0 |
| 5 | 5 | 23.044 | 1.354 | 171.3 | 3944.4 |
| 5 | 6 | 23.758 | 1.375 | 173.1 | 4111.9 |
| 5 | 7 | 24.484 | 1.396 | 174.6 | 4275.4 |
| 5 | 8 | 25.220 | 1.417 | 176.4 | 4448.0 |
| 5 | 9 | 25.967 | 1.437 | 178.1 | 4625.2 |
| 5 | 10 | 26.725 | 1.458 | 179.8 | 4806.1 |
| 5 | 11 | 27.494 | 1.479 | 181.4 | 4986.1 |
| 6 | 0 | 28.274 | 1.500 | 183.1 | 5176.3 |
| 6 | 3 | 30.680 | 1.562 | 187.9 | 5764.0 |
| 6 | 6 | 33.183 | 1.625 | 192.7 | 6394.9 |
| 6 | 9 | 35.785 | 1.687 | 197.2 | 7057.1 |
| 7 | 0 | 38.485 | 1.750 | 202.0 | 7774.3 |
| 7 | 3 | 41.283 | 1.812 | 206.5 | 8522.9 |
| 7 | 6 | 44.179 | 1.875 | 210.9 | 9318.3 |
| 7 | 9 | 47.173 | 1.937 | 215.4 | 10162. |
| 8 | 0 | 50.266 | 2.000 | 219.7 | 11044. |
| 8 | 3 | 53.456 | 2.062 | 224.0 | 11978. |
| 8 | 6 | 56.745 | 2.125 | 228.3 | 12954. |
| 8 | 9 | 60.132 | 2.187 | 232.4 | 13974. |
| 9 | 0 | 63.617 | 2.250 | 236.6 | 15049. |
| 9 | 3 | 67.201 | 2.312 | 240.7 | 16173. |
| 9 | 6 | 70.882 | 2.375 | 244.6 | 17338. |
| 9 | 9 | 74.662 | 2.437 | 248.6 | 18558. |
| 10 | 0 | 78 540 | 2.500 | 252.5 | 19834. |
| 10 | 3 | 82.516 | 2.562 | 256.5 | 21166. |
| 10 | 6 | 86.590 | 2.625 | 260.2 | 22534. |

**TABLE 2.—Kutter's formula with $n$=.011.**

| $d$=diameter in | | $a$=area in square feet. | $r$=hydraulic mean depth in feet. | For velocity $c\sqrt{r}$. | For discharge $ac\sqrt{r}$. |
|---|---|---|---|---|---|
| ft. | ins. | | | | |
| 10 | 9 | 90.763 | 2.687 | 264.0 | 23951. |
| 11 | 0 | 95.033 | 2.750 | 267.7 | 25444. |
| 11 | 3 | 99.402 | 2.812 | 271.5 | 26987. |
| 11 | 6 | 103.869 | 2.875 | 275.3 | 28593. |
| 11 | 9 | 108.434 | 3.937 | 278.8 | 30235. |
| 12 | 0 | 113.098 | 3.000 | 282.4 | 31937. |
| 12 | 3 | 117.859 | 3.062 | 286.0 | 33702. |
| 12 | 6 | 122.719 | 2.125 | 289.5 | 35529. |
| 12 | 9 | 127.677 | 3.187 | 292.9 | 37399. |
| 13 | 0 | 132.733 | 3.250 | 296.5 | 39358. |
| 13 | 3 | 137.887 | 3.312 | 299.9 | 41352. |
| 13 | 6 | 143.139 | 3.375 | 303.3 | 43412. |
| 13 | 9 | 148.490 | 3.437 | 306.7 | 45543. |
| 14 | 0 | 153.938 | 3.500 | 310 1 | 47739. |
| 14 | 6 | 165.130 | 3.625 | 316.8 | 52308. |
| 15 | 0 | 176.715 | 3.750 | 323.1 | 57103. |
| 15 | 6 | 188.692 | 3.875 | 329.6 | 62186. |
| 16 | 0 | 201.062 | 4.000 | 336.0 | 67557. |
| 16 | 6 | 213.825 | 4.125 | 342.2 | 73176. |
| 17 | 0 | 226.981 | 4.250 | 348.3 | 79050. |
| 17 | 6 | 240.529 | 4.375 | 354.3 | 85229. |
| 18 | 0 | 254.470 | 4.500 | 360.4 | 91711. |
| 19 | 0 | 283.529 | 4.750 | 372.3 | 105570. |
| 20 | 0 | 314.159 | 5.000 | 383.8 | 120570. |

## TABLE 3.—Circular Pipes, Sewers, Conduits, etc., flowing full. Kutter's formula with $n$=.012.

Table giving the values of $a$ and $r$ and also the values of the factors $c\sqrt{r}$ and $ac\sqrt{r}$ for use in the formulæ.

$$V=c\sqrt{r}\times\sqrt{s} \qquad Q=ac\sqrt{r}\times\sqrt{s}$$

These factors are to be used only where the value of $n$, that is the coefficient of roughness of lining of channel, =.012, as for unplaned timber when perfectly continuous on the inside and also flumes.

| $d$=diameter in | | $a$=area in square feet. | $r$=hydraulic mean depth in feet. | For velocity $c\sqrt{r}$. | For discharge $ac\sqrt{r}$. |
|---|---|---|---|---|---|
| ft. | ins. | | | | |
| 0 | 5 | 0.136 | 0.104 | 23.70 | 3.2234 |
| 0 | 6 | 0.196 | 0.125 | 27.45 | 5.3800 |
| 0 | 7 | 0.267 | 0.146 | 31.05 | 8.2911 |
| 0 | 8 | 0.349 | 0.167 | 34.51 | 12.042 |
| 0 | 9 | 0.442 | 0.187 | 37.80 | 16.708 |
| 0 | 10 | 0.545 | 0.208 | 40.95 | 22.317 |
| 0 | 11 | 0.666 | 0.229 | 44.22 | 29.183 |
| 1 | 0 | 0.785 | 0.250 | 47.30 | 37.149 |

TABLE 3.—Kutter's formula with $n=.012$.

| $d$=diameter in ft. | ins. | $a$=area in square feet. | $r$=hydraulic mean depth in feet. | For velocity $c\sqrt{r}$. | For discharge $ac\sqrt{r}$. |
|---|---|---|---|---|---|
| 1 | 1 | 0.922 | 0.271 | 50.11 | 46.199 |
| 1 | 2 | 1.069 | 0.292 | 52.99 | 56.641 |
| 1 | 3 | 1.227 | 0.312 | 55.78 | 68.445 |
| 1 | 4 | 1.396 | 0.333 | 58.50 | 81.661 |
| 1 | 5 | 1.576 | 0.354 | 61.26 | 96.548 |
| 1 | 6 | 1.767 | 0.375 | 63.83 | 112.79 |
| 1 | 7 | 1.969 | 0.397 | 66.41 | 130.76 |
| 1 | 8 | 2.182 | 0.417 | 69.03 | 150.61 |
| 1 | 9 | 2.405 | 0.437 | 71.38 | 171.66 |
| 1 | 10 | 2.640 | 0.458 | 73.92 | 195.14 |
| 1 | 11 | 2.885 | 0.479 | 76.33 | 220.21 |
| 2 | 0 | 3.142 | 0.500 | 78.72 | 247.33 |
| 2 | 1 | 3.409 | 0.521 | 81.07 | 276.38 |
| 2 | 2 | 3.687 | 0.542 | 83.29 | 307.10 |
| 2 | 3 | 3.976 | 0.562 | 85.54 | 340.10 |
| 2 | 4 | 4.276 | 0.583 | 87.81 | 375.46 |
| 2 | 5 | 4.587 | 0.604 | 89.94 | 412.54 |
| 2 | 6 | 4.909 | 0.625 | 92.09 | 452.07 |
| 2 | 7 | 5.241 | 0.646 | 94.41 | 494.78 |
| 2 | 8 | 5.585 | 0.667 | 96.52 | 539.07 |
| 2 | 9 | 5.939 | 0.687 | 98.49 | 584.90 |
| 2 | 10 | 6.305 | 0.708 | 100.6 | 634.46 |
| 2 | 11 | 6.681 | 0.729 | 102.6 | 685.64 |
| 3 | 0 | 7.068 | 0.750 | 104.6 | 739.59 |
| 3 | 1 | 7.466 | 0.771 | 106.7 | 796.38 |
| 3 | 2 | 7.875 | 0.792 | 108.7 | 856.12 |
| 3 | 3 | 8.295 | 0.812 | 110.6 | 917.41 |

TABLE 3.—Kutter's formula with $n=.012$.

| $d$=diameter in ft. | ins. | $a$=area in square feet. | $r$=hydraulic mean depth in feet. | For velocity $c\sqrt{r}$. | For discharge $ac\sqrt{r}$. |
|---|---|---|---|---|---|
| 3 | 4 | 8.726 | 0.833 | 112.6 | 982.39 |
| 3 | 5 | 9.169 | 0.854 | 114.4 | 1049.1 |
| 3 | 6 | 9.621 | 0.875 | 116.3 | 1118.6 |
| 3 | 7 | 10.084 | 0.896 | 118.1 | 1191.1 |
| 3 | 8 | 10.559 | 0.917 | 120.0 | 1267.0 |
| 3 | 9 | 11.044 | 0.937 | 121.9 | 1345.9 |
| 3 | 10 | 11.541 | 0.958 | 123.8 | 1428.3 |
| 3 | 11 | 12.048 | 0.979 | 125.7 | 1514.0 |
| 4 | 0 | 12.566 | 1.000 | 127.4 | 1600.9 |
| 4 | 1 | 13.096 | 1.021 | 129.1 | 1690.7 |
| 4 | 2 | 13.635 | 1.042 | 131.0 | 1785.8 |
| 4 | 3 | 14.186 | 1.062 | 132.7 | 1882.3 |
| 4 | 4 | 14.748 | 1.083 | 134.4 | 1982.3 |
| 4 | 5 | 15.321 | 1.104 | 136.2 | 2085.9 |
| 4 | 6 | 15.904 | 1.125 | 137.9 | 2193.0 |
| 4 | 7 | 16.499 | 1.146 | 139.5 | 2301.0 |
| 4 | 8 | 17.104 | 1.167 | 141.2 | 2415.4 |
| 4 | 9 | 17.721 | 1.187 | 142.8 | 2530.8 |
| 4 | 10 | 18.348 | 1.208 | 144.6 | 2652.8 |
| 4 | 11 | 18.986 | 1.229 | 146.3 | 2777.8 |
| 5 | 0 | 19.635 | 1.250 | 147.9 | 2903.6 |
| 5 | 1 | 20.295 | 1.271 | 149.4 | 3032.9 |
| 5 | 2 | 20.966 | 1.292 | 151.2 | 3169.8 |
| 5 | 3 | 21.648 | 1.313 | 152.8 | 3307.0 |
| 5 | 4 | 22.340 | 1.333 | 154.4 | 3448.3 |
| 5 | 5 | 23.044 | 1.354 | 155.9 | 3593.5 |
| 5 | 6 | 23.758 | 1.375 | 157.5 | 3742.7 |

TABLE 3.—Kutter's formula with $n$=.012.

| $d$=diameter in ft. | ins. | $a$=area in square feet. | $r$=hydraulic mean depth in feet. | For velocity $c\sqrt{r}$. | For discharge $ac\sqrt{r}$. |
|---|---|---|---|---|---|
| 5 | 7 | 24.484 | 1.396 | 159.0 | 3892.0 |
| 5 | 8 | 25.220 | 1 417 | 160.6 | 4049.5 |
| 5 | 9 | 25.967 | 1.437 | 162.2 | 4211.2 |
| 5 | 10 | 26.729 | 1.458 | 163.8 | 4376.4 |
| 5 | 11 | 27.494 | 1.479 | 165.1 | 4540.5 |
| 6 | 0 | 28.274 | 1.500 | 166.7 | 4713.9 |
| 6 | 3 | 30.680 | 1.562 | 171.1 | 5250.1 |
| 6 | 6 | 33.183 | 1.625 | 175.6 | 5825.9 |
| 6 | 9 | 35.785 | 1.687 | 179.9 | 6436.7 |
| 7 | 0 | 38.485 | 1.750 | 184.2 | 7087.0 |
| 7 | 3 | 41.283 | 1.812 | 188.3 | 7772.7 |
| 7 | 6 | 44.179 | 1.879 | 192.4 | 8501.8 |
| 7 | 9 | 47.173 | 1.937 | 196.6 | 9275.8 |
| 8 | 0 | 50.266 | 2.000 | 200.6 | 10083. |
| 8 | 3 | 53.456 | 2.062 | 204.5 | 10934. |
| 8 | 6 | 56.745 | 2.125 | 208.5 | 11832. |
| 8 | 9 | 60.132 | 2.187 | 212.3 | 12766. |
| 9 | 0 | 63.617 | 2.250 | 216.2 | 13751. |
| 9 | 3 | 67.201 | 2.312 | 219.9 | 14780. |
| 9 | 6 | 70.882 | 2.375 | 223.6 | 15847. |
| 9 | 9 | 74.662 | 2.437 | 227.2 | 16965. |
| 10 | 0 | 78.540 | 2.500 | 230.9 | 18134. |
| 10 | 3 | 82.516 | 2.562 | 234.6 | 19356. |
| 10 | 6 | 86.590 | 2.625 | 238.0 | 20612. |
| 10 | 9 | 90.763 | 2.687 | 241.5 | 21921. |
| 11 | 0 | 95.033 | 2.750 | 245.0 | 23285. |
| 11 | 3 | 99.402 | 2.812 | 248.5 | 24703. |

TABLE 8.—Kutter's formula with $n$=.012.

| $d$=diameter in ft. | ins. | $a$=area in square feet. | $r$=hydraulic mean depth in feet. | For velocity $c\sqrt{r}$. | For discharge $ac\sqrt{r}$. |
|---|---|---|---|---|---|
| 11 | 6 | 103.869 | 2.875 | 252.0 | 26179. |
| 11 | 9 | 108.434 | 2.937 | 255.4 | 27689. |
| 12 | 0 | 113.098 | 3.000 | 258.7 | 29254. |
| 12 | 3 | 117.859 | 3.062 | 262.0 | 30876. |
| 12 | 6 | 122.719 | 3.125 | 265.3 | 32558. |
| 12 | 9 | 127.677 | 3.187 | 268.5 | 34277. |
| 13 | 0 | 132.733 | 3.250 | 271.8 | 36077. |
| 13 | 3 | 137.887 | 3.312 | 274.9 | 37909. |
| 13 | 6 | 143.139 | 3.375 | 278.1 | 39802. |
| 13 | 9 | 148.490 | 3.437 | 281.2 | 41755. |
| 14 | 0 | 153.938 | 3.500 | 284.4 | 43773. |
| 14 | 6 | 165.130 | 3.625 | 290.5 | 47969. |
| 15 | 0 | 176.715 | 3.750 | 296.4 | 52382. |
| 15 | 6 | 188.692 | 3.875 | 302.4 | 57061. |
| 16 | 0 | 201.062 | 4.000 | 308.4 | 62008. |
| 16 | 6 | 213.825 | 4.125 | 314.2 | 67183. |
| 17 | 0 | 226.981 | 5.250 | 319.8 | 72594. |
| 17 | 6 | 240.529 | 4.375 | 325.5 | 78289. |
| 18 | 0 | 254.470 | 4.500 | 331.1 | 84247. |
| 19 | 0 | 282.529 | 4.750 | 342.1 | 96991. |
| 20 | 0 | 314.149 | 5.000 | 352.6 | 110905. |

**TABLE 4.**—Circular Pipes, Sewers, Conduits, etc., flowing full. Kutter's formula with $n=.013$.

Table giving the values of $a$ and $r$ and also the values of factors $c\sqrt{r}$ and $ac\sqrt{r}$ for use in the formulæ,

$$V=c\sqrt{r}\times\sqrt{s}\qquad Q=ac\sqrt{r}\times\sqrt{s}$$

These factors are to be used only where the value of $n$, that is the coefficient of roughness of lining of channel, $=.013$, as in ashlar and well laid brickwork, ordinary metal, earthenware and stoneware pipe, in good condition, but not new, cement and terra-cotta pipe not well jointed nor in perfect order, plaster and planed wood in imperfect or inferior condition, and also surfaces of other material equally rough.

| $d$=diameter in ft. | ins. | $a$=area in square feet. | $r$=hydraulic mean depth in feet. | For velocity $c\sqrt{r}$. | For discharge $ac\sqrt{r}$. |
|---|---|---|---|---|---|
| 0 | 5 | 0.136 | 0.104 | 21.20 | 2.8839 |
| 0 | 6 | 0.196 | 0.125 | 24.60 | 4.8216 |
| 0 | 7 | 0.267 | 0.146 | 27.87 | 7.4425 |

**TABLE 4.—Kutter's formula with $n$=.013.**

| $d$=diameter in ft. | ins. | $a$=area in square feet. | $r$=hydraulic mean depth in feet. | For velocity $c\sqrt{r}$. | For discharge $ac\sqrt{r}$. |
|---|---|---|---|---|---|
| 0 | 8 | 0.349 | 0.167 | 31.00 | 10.822 |
| 0 | 9 | 0.442 | 0.187 | 34.00 | 15.029 |
| 0 | 10 | 0.545 | 0.208 | 36.87 | 20.095 |
| 0 | 11 | 0.660 | 0.229 | 39.84 | 26.296 |
| 1 | 0 | 0.785 | 0.250 | 42.65 | 33.497 |
| 1 | 1 | 0.922 | 0.271 | 45.22 | 41.692 |
| 1 | 2 | 1.069 | 0.292 | 47.85 | 51.157 |
| 1 | 3 | 1.227 | 0.312 | 50.42 | 61.867 |
| 1 | 4 | 1.396 | 0.333 | 52.90 | 73.855 |
| 1 | 5 | 1.576 | 0.354 | 55.44 | 87.376 |
| 1 | 6 | 1.767 | 0.375 | 57.80 | 102.14 |
| 1 | 7 | 1.969 | 0.396 | 60.17 | 118.47 |
| 1 | 8 | 2.182 | 0.417 | 62.58 | 136.54 |
| 1 | 9 | 2.405 | 0.437 | 64.73 | 155.68 |
| 1 | 10 | 2.640 | 0.458 | 67.07 | 177.07 |
| 1 | 11 | 2.885 | 0.479 | 69.29 | 199.90 |
| 2 | 0 | 3.142 | 0.500 | 71.49 | 224.63 |
| 2 | 1 | 3.409 | 0.521 | 73.66 | 251.10 |
| 2 | 2 | 3.687 | 0.542 | 75.70 | 279.12 |
| 2 | 3 | 3.976 | 0.562 | 77.77 | 309.23 |
| 2 | 4 | 4.276 | 0.583 | 79.87 | 341.52 |
| 2 | 5 | 4.587 | 0.604 | 81.83 | 375.37 |
| 2 | 6 | 4.909 | 0.625 | 83.82 | 411.27 |
| 2 | 7 | 5.241 | 0.648 | 85.95 | 450.49 |
| 2 | 8 | 5.585 | 0.667 | 87.89 | 490.88 |
| 2 | 9 | 5.939 | 0.687 | 89.71 | 532.76 |
| 2 | 10 | 6.305 | 0.708 | 91.68 | 578.02 |

### TABLE 4.—Kutter's formula with $n$=.013.

| $d$=diameter in | | $a$=area in square feet. | $r$=hydraulic mean depth in feet. | For velocity $c\sqrt{r}$. | For discharge $ac\sqrt{r}$. |
|---|---|---|---|---|---|
| ft. | ins. | | | | |
| 2 | 11 | 6.681 | 0.729 | 93.52 | 624.82 |
| 3 | 0 | 7.068 | 0.750 | 95.37 | 674.09 |
| 3 | 1 | 7.466 | 0.771 | 97.25 | 726.05 |
| 3 | 2 | 7.875 | 0.792 | 99.13 | 780.63 |
| 3 | 3 | 8.295 | 0.812 | 100.9 | 836.69 |
| 3 | 4 | 8.726 | 0.833 | 102.8 | 896.27 |
| 3 | 5 | 9.169 | 0.854 | 104.4 | 957.35 |
| 3 | 6 | 9.621 | 0.875 | 106.1 | 1021.1 |
| 3 | 7 | 10.084 | 0.896 | 107.9 | 1087.7 |
| 3 | 8 | 10 559 | 0.917 | 109.6 | 1157.2 |
| 3 | 9 | 11.044 | 0.937 | 111.3 | 1229.7 |
| 3 | 10 | 11.541 | 0.958 | 113.1 | 1305.3 |
| 3 | 11 | 12.048 | 0.979 | 114.9 | 1384 1 |
| 4 | 0 | 12.566 | 1.000 | 116.5 | 1463.9 |
| 4 | 1 | 13.096 | 1.021 | 118.1 | 1546.9 |
| 4 | 2 | 13.635 | 1.042 | 119.8 | 1633.5 |
| 4 | 3 | 14.186 | 1.062 | 121.4 | 1722.0 |
| 4 | 4 | 14.748 | 1.083 | 123.0 | 1813.8 |
| 4 | 5 | 15.321 | 1.104 | 124.6 | 1908.0 |
| 4 | 6 | 15.904 | 1.125 | 126.2 | 2007.0 |
| 4 | 7 | 16.499 | 1.146 | 127.7 | 2206.1 |
| 4 | 8 | 17.104 | 1.167 | 129.3 | 2211.1 |
| 4 | 9 | 17.721 | 1.187 | 130.7 | 2316.9 |
| 4 | 10 | 18.348 | 1.208 | 132.4 | 2429.1 |
| 4 | 11 | 18.986 | 1.229 | 134.0 | 2543.9 |
| 5 | 0 | 19.635 | 1.250 | 135.4 | 2659.0 |
| 5 | 1 | 20.205 | 1.271 | 136.9 | 2778.7 |

TABLE 4.—Kutter's formula with $n$=.013.

| $d$=diameter in | | $a$=area in square feet. | $r$=hydraulic mean depth in feet. | For velocity $c\sqrt{r}$. | For discharge $ac\sqrt{r}$. |
|---|---|---|---|---|---|
| ft. | ins. | | | | |
| 5 | 2 | 20.966 | 1.292 | 138.5 | 2903.5 |
| 5 | 3 | 21.648 | 1.312 | 139.9 | 3029.4 |
| 5 | 4 | 22.340 | 1.333 | 141.4 | 3159.0 |
| 5 | 5 | 23.044 | 1.354 | 142.9 | 3292.3 |
| 5 | 6 | 23.758 | 1.375 | 144.3 | 3429.2 |
| 5 | 7 | 24.484 | 1.396 | 145.6 | 3566.2 |
| 5 | 8 | 25.220 | 1.417 | 147.1 | 3710.9 |
| 5 | 9 | 25.967 | 1.437 | 148.6 | 3859.7 |
| 5 | 10 | 26.729 | 1.458 | 150.1 | 4012.2 |
| 5 | 11 | 27.494 | 1.479 | 151.4 | 4162.7 |
| 6 | 0 | 28.274 | 1.500 | 152.9 | 4322.9 |
| 6 | 3 | 30.680 | 1.562 | 157.0 | 4816.8 |
| 6 | 6 | 33.183 | 1.625 | 161.2 | 5339.7 |
| 6 | 9 | 35.785 | 1.687 | 165.2 | 5911.5 |
| 7 | 0 | 38.485 | 1.750 | 169.2 | 6510.6 |
| 7 | 3 | 41.283 | 1.812 | 173.0 | 7142.0 |
| 7 | 6 | 44.179 | 1.879 | 176.9 | 7814.2 |
| 7 | 9 | 47.173 | 1.937 | 180.8 | 8527.9 |
| 8 | 0 | 50.266 | 2.000 | 184.5 | 9272.6 |
| 8 | 3 | 53.456 | 2.062 | 188.2 | 10059. |
| 8 | 6 | 56.745 | 2.125 | 191.9 | 10889. |
| 8 | 9 | 60.132 | 2.187 | 195.4 | 11753. |
| 9 | 0 | 63.617 | 2.250 | 199.1 | 12663. |
| 9 | 3 | 67.201 | 2.312 | 202.6 | 13613. |
| 9 | 6 | 70.882 | 2.375 | 205.9 | 14597. |
| 9 | 9 | 74.662 | 2.437 | 209.3 | 15629. |
| 10 | 0 | 78.540 | 2.500 | 212.8 | 16709.0 |

TABLE 4.—Kutter's formula with $n$=.013.

| $d$=diameter in | | $a$=area in square feet. | $r$=hydraulic mean depth in feet. | For velocity $c\sqrt{r}$. | For discharge $ac\sqrt{r}$. |
|---|---|---|---|---|---|
| ft. | ins. | | | | |
| 10 | 3 | 82.516 | 2.562 | 216.2 | 17837. |
| 10 | 6 | 86.590 | 2.625 | 219.4 | 18996. |
| 10 | 9 | 90.763 | 2.687 | 222.6 | 20205. |
| 11 | 0 | 95.033 | 2.750 | 225.9 | 21464. |
| 11 | 3 | 99.402 | 2.812 | 229.1 | 22774. |
| 11 | 6 | 103.869 | 2.875 | 232.4 | 24139. |
| 11 | 9 | 108.434 | 2.937 | 235.4 | 25533. |
| 12 | 0 | 113.098 | 3.000 | 238.6 | 26981. |
| 12 | 3 | 117.859 | 3.062 | 241.7 | 28484. |
| 12 | 6 | 122.719 | 3.125 | 244.8 | 30041. |
| 12 | 9 | 127.677 | 3.187 | 247.8 | 31633. |
| 13 | 0 | 132.733 | 3.250 | 250.9 | 33301. |
| 13 | 3 | 137.887 | 3.312 | 253.8 | 34998. |
| 13 | 6 | 143.139 | 3.375 | 256.8 | 36752. |
| 13 | 9 | 148.490 | 3.437 | 259.7 | 38561. |
| 14 | 0 | 153.938 | 3.500 | 262.6 | 40432. |
| 14 | 6 | 165.130 | 3.625 | 268.4 | 44322. |
| 15 | 0 | 176.715 | 3.750 | 274.0 | 48413. |
| 15 | 6 | 188.692 | 3.875 | 279.6 | 52753. |
| 16 | 0 | 201.062 | 4.000 | 285.2 | 57343. |
| 16 | 6 | 213.825 | 4.125 | 290.6 | 62132. |
| 17 | 0 | 226.981 | 4.250 | 295.8 | 67140. |
| 17 | 6 | 240.529 | 4.375 | 301.0 | 72409. |
| 18 | 0 | 254.470 | 4.500 | 306.3 | 77932. |
| 19 | 0 | 282.529 | 4.75. | 316.6 | 89759. |
| 20 | 0 | 314.159 | 5.000 | 326.5 | 102559. |

**Table 5.**—Value of $c\sqrt{r}$ to be used *only* in the use of the second type of the use of Bazin's formula for *open channels* with an even lining of cut stone, brick-work, or other material with surfaces of equal roughness exposed to the flow of water. This formula is

$$V = c\sqrt{r} \times \sqrt{s}$$

where
$$c = \sqrt{1 \div .000013\left(4.354 + \frac{1}{r}\right)}$$

| Hydraulic mean depth in feet, $r$. | $c\sqrt{r}$ | Hydraulic mean depth in feet, $r$. | $c\sqrt{r}$ |
|---|---|---|---|
| 0.104 | 23.710 | 0.312 | 55.783 |
| 0.125 | 27.617 | 0.333 | 58.346 |
| 0.146 | 31.284 | 0.354 | 60.898 |
| 0.167 | 34.569 | 0.375 | 63.336 |
| 0.187 | 38.147 | 0.396 | 65.756 |
| 0.208 | 41.327 | 0.417 | 68.159 |
| 0.229 | 44.484 | 0.437 | 70.337 |
| 0.250 | 47.430 | 0.458 | 72.615 |
| 0.271 | 50.267 | 0.479 | 74.764 |
| 0.292 | 53.077 | 0.500 | 76.907 |

**TABLE 5.—Value of $c\sqrt{r}$ in Bazin's Formula, Second Category.**

| Hydraulic mean depth in feet, *r*. | $c\sqrt{r}$ | Hydraulic mean depth in feet, *r*. | $c\sqrt{r}$ |
|---|---|---|---|
| 0.562 | 83.048 | 1.750 | 163.46 |
| 0.625 | 88.772 | 1.875 | 169.80 |
| 0.687 | 94.315 | 2.000 | 175.99 |
| 0.750 | 99.573 | 2.125 | 182.02 |
| 0.812 | 104.53 | 2.250 | 187.77 |
| 0.875 | 109.35 | 2.375 | 193.36 |
| 0.937 | 114 00 | 2.500 | 198.83 |
| 1.000 | 118.50 | 2.750 | 209.31 |
| 1.062 | 122.82 | 3.000 | 219.36 |
| 1.125 | 127.05 | 3.250 | 228.98 |
| 1.187 | 131.00 | 3.500 | 238.18 |
| 1.250 | 135.03 | 3.750 | 246.96 |
| 1.312 | 138.93 | 4.000 | 255.58 |
| 1.375 | 142.79 | 4.250 | 263.81 |
| 1.437 | 146.42 | 4.500 | 271.87 |
| 1.500 | 149.90 | 4.750 | 279.78 |
| 1.625 | 156.83 | 5.000 | 287.30 |

### TABLE 6.—Values of $\sqrt{r}$ for diameters given in Tables.

| Diameter. |  | $\sqrt{r}$. | Diameter. |  | $\sqrt{r}$ |
|---|---|---|---|---|---|
| Ft. | Ins. | in Feet. | Ft. | Ins. | in Feet. |
| 0 | 5 | 0.323 | 2 | 9 | 0.829 |
| 0 | 6 | 0.354 | 2 | 10 | 0.842 |
| 0 | 7 | 0.382 | 2 | 11 | 0.854 |
| 0 | 8 | 0 408 | 3 | 0 | 0.866 |
| 0 | 9 | 0.433 | 3 | 1 | 0 878 |
| 0 | 10 | 0.456 | 3 | 2 | 0.890 |
| 0 | 11 | 0.479 | 3 | 3 | 0.901 |
| 1 | 0 | 0.500 | 3 | 4 | 0.913 |
| 1 | 1 | 0.520 | 3 | 5 | 0.924 |
| 1 | 2 | 0.540 | 3 | 6 | 0.935 |
| 1 | 6 | 0.559 | 3 | 7 | 0.946 |
| 1 | 4 | 0.577 | 3 | 8 | 0.957 |
| 1 | 5 | 0.595 | 3 | 9 | 0.968 |
| 1 | 6 | 0.612 | 3 | 10 | 0.979 |
| 1 | 7 | 0.629 | 3 | 11 | 0 990 |
| 1 | 8 | 0.646 | 4 | 0 | 1.000 |
| 1 | 9 | 0.661 | 4 | 1 | 1.010 |
| 1 | 10 | 0.677 | 4 | 2 | 1.021 |
| 1 | 11 | 0.692 | 4 | 3 | 1.031 |
| 2 | 0 | 0.707 | 4 | 4 | 1.041 |
| 2 | 1 | 0.722 | 4 | 5 | 1.051 |
| 2 | 2 | 0.736 | 4 | 6 | 1.061 |
| 2 | 3 | 0.750 | 4 | 7 | 1.070 |
| 2 | 4 | 0 764 | 4 | 8 | 1.080 |
| 2 | 5 | 0.777 | 4 | 9 | 1.089 |
| 2 | 6 | 0.790 | 4 | 10 | 1.099 |
| 2 | 7 | 0.804 | 4 | 11 | 1.109 |
| 2 | 8 | 0.817 | 5 | 0 | 1 118 |

## TABLE 6.—Values of $\sqrt{r}$ for diameters given in Tables.

| Diameter. Ft. | Diameter. Ins. | $\sqrt{r}$ in Feet. | Diameter. Ft. | Diameter. Ins. | $\sqrt{s}$ in Feet. |
|---|---|---|---|---|---|
| 5 | 1 | 1.127 | 10 | 0 | 1.581 |
| 5 | 2 | 1.137 | 10 | 3 | 1.601 |
| 5 | 3 | 1.146 | 10 | 6 | 1.620 |
| 5 | 4 | 1.155 | 10 | 9 | 1.639 |
| 5 | 5 | 1.164 | 11 | 0 | 1.658 |
| 5 | 6 | 1 173 | 11 | 3 | 1.677 |
| 5 | 7 | 1.181 | 11 | 6 | 1.696 |
| 5 | 8 | 1.190 | 11 | 9 | 1.714 |
| 5 | 9 | 1.199 | 12 | 0 | 1.732 |
| 5 | 10 | 1.208 | 12 | 3 | 1.750 |
| 5 | 11 | 1.216 | 12 | 6 | 1.768 |
| 6 | 0 | 1.225 | 12 | 9 | 1.785 |
| 6 | 3 | 1.250 | 13 | 0 | 1.803 |
| 6 | 6 | 1.275 | 13 | 3 | 1.820 |
| 6 | 9 | 1.299 | 13 | 6 | 1.837 |
| 7 | 0 | 1.323 | 13 | 9 | 1.854 |
| 7 | 3 | 1.346 | 14 | 0 | 1.871 |
| 7 | 6 | 1.369 | 14 | 6 | 1.904 |
| 7 | 9 | 1.392 | 15 | 0 | 1.936 |
| 8 | 0 | 1.414 | 15 | 6 | 1.968 |
| 8 | 3 | 1.436 | 16 | 0 | 2.000 |
| 8 | 6 | 1.458 | 16 | 6 | 2.031 |
| 8 | 9 | 1.479 | 17 | 0 | 2.061 |
| 9 | 0 | 1.500 | 17 | 6 | 2.091 |
| 9 | 3 | 1.521 | 18 | 0 | 2.121 |
| 9 | 6 | 1.541 | 19 | 0 | 2.180 |
| 9 | 9 | 1.561 | 20 | 0 | 2.236 |

**Table 7.**—Giving fall in feet per mile; the distance corresponding to a fall of one foot, and also the values of $s$ and $\sqrt{s}$.

$s = \frac{h}{l} =$ sine of slope = fall of water surface ($h$) in any distance ($l$) divided by that distance.

| Fall in feet per mile. | Slope, one in | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1 | 5280. | .000189393 | .013762 |
| 2 | 2640. | .000378787 | .019463 |
| 3 | 1760. | .000568182 | .023836 |
| 4 | 1320. | .000757576 | .027524 |
| 5 | 1056. | .000946969 | .030773 |
| 6 | 880.0 | .001136364 | .033710 |
| 7 | 754.3 | .001325797 | .036411 |
| 8 | 660.0 | .001515151 | .038925 |
| 9 | 586.6 | .001704445 | .041286 |
| 10 | 528.0 | .001893939 | .043519 |
| 11 | 443.6 | .002083333 | .045643 |
| 12 | 440.0 | .002272727 | .047673 |
| 13 | 406.1 | .002462121 | .049620 |
| 14 | 377.1 | .002651515 | .051493 |
| 15 | 352.0 | .002840909 | .053300 |
| 16 | 330.0 | .003030303 | .055048 |
| 17 | 310.6 | .003219696 | .056742 |
| 18 | 293.3 | .003409090 | .058388 |
| 19 | 277.9 | .003598484 | .059988 |
| 20 | 264.0 | .003787878 | .061546 |
| 21 | 251.4 | .003977272 | .063066 |

### TABLE 7.—Slopes.

| Fall in feet per mile. | Slope, one in | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 22 | 240.0 | .004166667 | .064549 |
| 23 | 229.6 | .004356060 | .066000 |
| 24 | 220.0 | .004545454 | .067419 |
| 25 | 211.2 | .004734848 | .068810 |
| 26 | 203.1 | .004924242 | .070173 |
| 27 | 195.2 | .005113636 | .071510 |
| 28 | 188.6 | .005303030 | .072822 |
| 29 | 182.1 | .005492424 | .074111 |
| 30 | 176.0 | .005681818 | .075378 |
| 31 | 170.3 | .005871219 | .076624 |
| 32 | 165.0 | .006060606 | .077850 |
| 33 | 160.0 | .006250000 | .079057 |
| 34 | 155.3 | .006439393 | .080246 |
| 35 | 150.9 | .006628788 | .081417 |
| 36 | 146.6 | .006818181 | .082572 |
| 37 | 142.7 | .007007575 | .083711 |
| 38 | 139.0 | .007196969 | .084836 |
| 39 | 135.4 | .007386363 | .085944 |
| 40 | 132.0 | .007575757 | .087039 |
| 41 | 128.8 | .007765151 | .088120 |
| 42 | 125.7 | .007954545 | .089188 |
| 43 | 122.8 | .008143939 | .090244 |
| 44 | 120.0 | .008333333 | .091287 |
| 45 | 117.3 | .008522727 | .092319 |
| 46 | 114.8 | .008712121 | .093339 |
| 47 | 112.3 | .008901515 | .094348 |
| 48 | 110.0 | .009090909 | .095346 |
| 49 | 107.7 | .009280303 | .096334 |
| 50 | 105.6 | .009469696 | .097312 |
| 51 | 103.5 | .009659090 | .098281 |
| 52 | 101.5 | .009848484 | .099241 |
| 53 | 99.60 | .010037871 | .100189 |

## TABLE 7.—Slopes.

| Fall in feet per mile. | Slope, one in | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 54 | 97.77 | .010227273 | .101130 |
| 55 | 96.00 | .010416667 | .102060 |
| 56 | 94.28 | .010606060 | .102983 |
| 57 | 92 63 | .010795454 | .103901 |
| 58 | 91.03 | .010984848 | .104809 |
| 59 | 89.49 | .011174242 | .105708 |
| 60 | 88.00 | .011363636 | .106600 |
| 65 | 81.23 | 012310606 | .110953 |
| 70 | 75.43 | .013257575 | .115141 |
| 80 | 66.00 | .015151515 | .123091 |
| 90 | 58.66 | .017045454 | .130559 |
| 100 | 52.80 | .018939393 | .137620 |
| 120 | 44.00 | .022727272 | .150756 |
| 140 | 37.71 | .026515151 | .162835 |
| 160 | 33.00 | .030303030 | .174077 |
| 180 | 29.33 | .034090909 | .184637 |
| 200 | 26.40 | .037878787 | .194625 |
| 240 | 22.00 | .041666667 | .213200 |
| 280 | 18.86 | .053030303 | .230283 |
| 320 | 16.50 | .060606060 | .246183 |
| 360 | 14.66 | .068181818 | .261116 |
| 400 | 13.20 | .075757575 | .275241 |
| 450 | 11.73 | .085227272 | .291937 |
| 500 | 10.56 | .094696969 | .307729 |
| 600 | 8.800 | .113636363 | .337100 |
| 700 | 7.543 | .132575757 | .364109 |
| 800 | 6.660 | .151515151 | .389249 |
| 900 | 5.866 | .170454545 | .412861 |
| 1000 | 5.280 | .189393939 | .435194 |
| 1500 | 3.520 | .284090909 | .532925 |

## TABLE 7.—Slopes continued.

(This table is a continuation of the Table of Slopes given in No. 67, Science Series, entitled "Hydraulic Tables Based on Kutter's Formula.")

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 100 | 52.80 | .010000000 | .100000 |
| 200 | 26.40 | .005000000 | .070710 |
| 300 | 17.60 | .003333333 | .057735 |
| 1001 | 5.274 | .000999000 | .031067 |
| 1002 | 5.269 | .000998004 | .061591 |
| 1003 | 5.264 | .000997008 | .031576 |
| 1004 | 5.259 | .000996016 | .031560 |
| 1005 | 5.253 | .000995025 | .031544 |
| 1006 | 5.248 | .000994036 | .031528 |
| 1007 | 5.243 | .000993048 | .031513 |
| 1008 | 5.238 | .000992064 | .031497 |
| 1009 | 5.233 | .000991080 | .031481 |
| 1010 | 5.228 | .000990099 | .031466 |
| 1011 | 5.222 | .000989120 | .031450 |
| 1012 | 5.217 | .000988142 | .031435 |
| 1013 | 5.212 | .000987167 | .031419 |
| 1014 | 5.207 | .000986193 | .031404 |
| 1015 | 5.202 | .000985222 | .031388 |
| 1016 | 5.197 | .000984252 | .031373 |
| 1017 | 5.192 | .000983284 | .031357 |
| 1018 | 5.187 | .000982318 | .031342 |
| 1019 | 5.181 | .000981354 | .031327 |
| 1020 | 5.176 | .000980392 | .031311 |
| 1021 | 5.171 | .000979432 | .031296 |
| 1022 | 5.166 | .000978571 | .031282 |
| 1023 | 5.161 | .000977517 | .031255 |

### TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1024 | 5.156 | .000976562 | .031250 |
| 1025 | 5.151 | .000975610 | .031235 |
| 1026 | 5.146 | .000974659 | .031219 |
| 1027 | 5.141 | .000973710 | .031204 |
| 1028 | 5.136 | .000972763 | .031189 |
| 1029 | 5.131 | .000971817 | .031174 |
| 1030 | 5.126 | .000970873 | .031159 |
| 1031 | 5.121 | .000969932 | .031144 |
| 1032 | 5.116 | .000968992 | .031129 |
| 1033 | 5.111 | .000968054 | .031114 |
| 1034 | 5.106 | .000967118 | .031099 |
| 1035 | 5.101 | .000966184 | .031083 |
| 1040 | 5.077 | .000961538 | .031009 |
| 1041 | 5.072 | .000960615 | .030994 |
| 1042 | 5.067 | .000959693 | .030975 |
| 1043 | 5.062 | .000958773 | .030964 |
| 1044 | 5.058 | .000957855 | .030949 |
| 1045 | 5.053 | .000956938 | .030934 |
| 1046 | 5.048 | .000956023 | .030919 |
| 1047 | 5.043 | .000955110 | .030905 |
| 1048 | 5.038 | .000954198 | .030890 |
| 1049 | 5.033 | .000953289 | .030875 |
| 1050 | 5.029 | .000952381 | .030861 |
| 1051 | 5.025 | .000951475 | .030846 |
| 1052 | 5.019 | .000950570 | .030831 |
| 1053 | 5.014 | .000949668 | .030817 |
| 1054 | 5.010 | .000948767 | .030802 |
| 1055 | 5.005 | .000947867 | .030787 |
| 1056 | 5.000 | .000946970 | .030773 |
| 1057 | 4.995 | .000946074 | .030758 |
| 1058 | 4.990 | .000945180 | .030744 |

## TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1059 | 4.986 | .000944287 | .030729 |
| 1060 | 4.981 | .000943396 | .030715 |
| 1061 | 4.976 | .000942507 | .030700 |
| 1062 | 4.972 | .000941620 | .030686 |
| 1063 | 4.967 | .000940734 | .030671 |
| 1064 | 4.962 | .000939850 | .030657 |
| 1065 | 4.958 | .000938967 | .030643 |
| 1066 | 4.953 | .000938086 | .030628 |
| 1067 | 4.948 | .000937207 | .030614 |
| 1068 | 4.944 | .000936330 | .030599 |
| 1069 | 4.939 | .000935454 | .030585 |
| 1070 | 4.935 | .000934579 | .030571 |
| 1071 | 4.930 | .000933707 | .030557 |
| 1072 | 4.925 | .000932836 | .030542 |
| 1073 | 4.921 | .000931967 | .030528 |
| 1074 | 4.916 | .000931099 | .030514 |
| 1075 | 4.912 | .000930233 | .030499 |
| 1076 | 4.907 | .000929368 | .030485 |
| 1077 | 4.902 | .000928505 | .030471 |
| 1078 | 4.898 | .000927644 | .030457 |
| 1079 | 4.893 | .000926784 | .030443 |
| 1080 | 4.889 | .000925926 | .030429 |
| 1081 | 4.884 | .000925069 | .030415 |
| 1082 | 4.880 | .000924214 | .030401 |
| 1083 | 4.875 | .000923361 | .030387 |
| 1084 | 4.871 | .000922509 | .030373 |
| 1085 | 4.866 | .000921659 | .030359 |
| 1086 | 4.862 | .000920819 | .030345 |
| 1087 | 4.857 | .000919954 | .030331 |
| 1088 | 4.853 | .000919118 | .030317 |
| 1089 | 4.848 | .000918274 | .030303 |

## TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1090 | 4.844 | .000917431 | .030289 |
| 1091 | 4.839 | .000916590 | .030275 |
| 1092 | 4.835 | .000915751 | .039261 |
| 1093 | 4.831 | .000914914 | .030247 |
| 1094 | 4.826 | .000914077 | .030234 |
| 1095 | 4.822 | .000913242 | .030220 |
| 1096 | 4.817 | .000912409 | .030206 |
| 1097 | 4.813 | .000911576 | .030192 |
| 1098 | 4.809 | .000910747 | .030178 |
| 1099 | 4.804 | .000909918 | .030165 |
| 1100 | 4.800 | .000909090 | .030151 |
| 1101 | 4.796 | .000908265 | .030137 |
| 1102 | 4.792 | .000907441 | .030124 |
| 1103 | 4.787 | .000906618 | .030110 |
| 1104 | 4.783 | .000905797 | .030096 |
| 1105 | 4.778 | .000904977 | .030083 |
| 1106 | 4.774 | .000904159 | .030069 |
| 1107 | 4.769 | .000903342 | .030055 |
| 1108 | 4.765 | .000902527 | .030042 |
| 1109 | 4.761 | .000901713 | .030028 |
| 1110 | 4.757 | .000900900 | .030015 |
| 1111 | 4.752 | .000900090 | .030001 |
| 1112 | 4.748 | .000899279 | .029988 |
| 1113 | 4.744 | .000898473 | .029975 |
| 1114 | 4.739 | .000897666 | .029961 |
| 1115 | 4.735 | .000896861 | .029948 |
| 1116 | 4.731 | .000896057 | .029934 |
| 1117 | 4.727 | .000893655 | .029921 |
| 1118 | 4.723 | .000894508 | .029908 |
| 1119 | 4.719 | .000893655 | .029894 |
| 1120 | 4.714 | .000892857 | .029881 |

## TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1121 | 4 710 | .000892061 | .029868 |
| 1122 | 4.706 | .000891266 | .029854 |
| 1223 | 4.702 | .000890472 | .029841 |
| 1124 | 4.698 | .000889680 | .029828 |
| 1125 | 4.693 | .000888888 | .029814 |
| 1126 | 4.689 | .000888099 | .029801 |
| 1127 | 4.685 | .000887311 | .029788 |
| 1128 | 4.681 | .000886525 | .029775 |
| 1129 | 4.677 | .000885740 | .029761 |
| 1130 | 4.673 | .000884956 | .029748 |
| 1131 | 4.668 | .000884173 | .029735 |
| 1132 | 4.664 | .000883392 | .029722 |
| 1133 | 4.660 | .000882623 | .029709 |
| 1134 | 4.656 | .000881834 | .029696 |
| 1135 | 4.652 | .000881057 | .029683 |
| 1136 | 4.648 | .000880282 | .029669 |
| 1137 | 4.644 | .000879507 | .029656 |
| 1138 | 4.640 | .000878734 | .029643 |
| 1139 | 4.636 | .000877963 | .029630 |
| 1140 | 4.632 | .000877193 | .029617 |
| 1141 | 4.628 | .000876424 | .029604 |
| 1142 | 4.623 | .000875744 | .029591 |
| 1143 | 4.619 | .000874890 | .029578 |
| 1144 | 4.615 | .000874126 | .029566 |
| 1145 | 4.611 | .000873365 | .029553 |
| 1146 | 4.607 | .000872600 | .029540 |
| 1147 | 4.603 | .000871840 | .029527 |
| 1148 | 4.599 | .000871080 | .029514 |
| 1149 | 4.595 | .000871192 | .029501 |
| 1150 | 4.591 | .000869566 | .029488 |
| 1151 | 4.587 | .000868810 | .029476 |

## TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1152 | 4.583 | .000868055 | .029463 |
| 1153 | 4.579 | .000867303 | .029450 |
| 1154 | 4.575 | .000866577 | .029438 |
| 1155 | 4.571 | .000865801 | .029425 |
| 1156 | 4.567 | .000865052 | .029412 |
| 1157 | 4.563 | .000864304 | .029399 |
| 1158 | 4.559 | .000863558 | .029386 |
| 1159 | 4.556 | .000862813 | .029374 |
| 1160 | 4.552 | .000862069 | .029363 |
| 1161 | 4.548 | .000861326 | .029348 |
| 1162 | 4.544 | .000860585 | .029336 |
| 1163 | 4.540 | .000859845 | .029323 |
| 1164 | 4.536 | .000859106 | .029311 |
| 1165 | 4.532 | .000858370 | .029298 |
| 1166 | 4.528 | .000857623 | .029285 |
| 1167 | 4.524 | .000856898 | .029273 |
| 1168 | 4.521 | .000856164 | .029264 |
| 1169 | 4.517 | .000855432 | .029248 |
| 1170 | 4.513 | .000854701 | .029235 |
| 1171 | 4.509 | .000853971 | .029223 |
| 1172 | 4.505 | .000853242 | .029210 |
| 1173 | 4.501 | .000852515 | .029198 |
| 1174 | 4.497 | .000851789 | .029185 |
| 1175 | 4.494 | .000851064 | .029173 |
| 1176 | 4.490 | .000850340 | .029161 |
| 1177 | 4.486 | .000849626 | .029148 |
| 1178 | 4.482 | .000848896 | .029136 |
| 1179 | 4.478 | .000848176 | .029123 |
| 1180 | 4.475 | .000847458 | .029111 |
| 1181 | 4.471 | .000846740 | .029099 |
| 1182 | 4.467 | .000846024 | .029086 |

## TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1183 | 4.463 | .000845309 | .029074 |
| 1184 | 4.459 | .000844595 | .029062 |
| 1185 | 4.456 | .000843882 | .029049 |
| 1186 | 4.452 | .000843170 | .020037 |
| 1187 | 4.448 | .000842460 | .029025 |
| 1188 | 4.444 | .000841751 | .029013 |
| 1189 | 4.441 | .000841043 | .029001 |
| 1190 | 4.437 | .000840336 | .028988 |
| 1191 | 4.433 | .000839631 | .028976 |
| 1192 | 4.430 | .000838926 | .028964 |
| 1193 | 4.426 | .000838223 | .028952 |
| 1194 | 4.422 | .000837521 | .028940 |
| 1195 | 4.418 | .000836820 | .028928 |
| 1196 | 4.415 | .000836120 | .028916 |
| 1197 | 4.411 | .000835422 | .028904 |
| 1198 | 4.407 | .000834725 | .028892 |
| 1199 | 4.404 | .000834028 | .028880 |
| 1200 | 4.400 | .000833333 | .028868 |
| 1201 | 4.396 | .000832639 | .028855 |
| 1202 | 4.393 | .000831946 | .028843 |
| 1203 | 4.389 | .000831255 | .028831 |
| 1204 | 4.385 | .000830565 | .028819 |
| 1205 | 4.382 | .000829875 | .028808 |
| 1206 | 4.378 | .000829187 | .028786 |
| 1207 | 4.374 | .000828500 | .028784 |
| 1208 | 4.371 | .000827815 | .028772 |
| 1209 | 4.367 | .000827129 | .028760 |
| 1210 | 4.364 | .000826446 | .028748 |
| 1211 | 4.360 | .000825764 | .028736 |
| 1212 | 4.356 | .000825083 | .028724 |
| 1213 | 4.353 | .000824402 | .028713 |

## TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | *s.* | $\sqrt{s.}$ |
|---|---|---|---|
| 1214 | 4.349 | .000823723 | .028701 |
| 1215 | 4.346 | .000823045 | .028689 |
| 1216 | 4.342 | .000822368 | 028677 |
| 1217 | 4.339 | .000821693 | .028665 |
| 1218 | 4.335 | .000821018 | .028653 |
| 1219 | 4.331 | .000820344 | .028641 |
| 1220 | 4.328 | .000819672 | .028630 |
| 1221 | 4.324 | .000819001 | .028617 |
| 1222 | 4.321 | .000818355 | .028506 |
| 1223 | 4.317 | .000817661 | .028595 |
| 1224 | 4.314 | .000816993 | .028583 |
| 1225 | 4.310 | .000816326 | .028571 |
| 1226 | 4.307 | .000815661 | .028559 |
| 1227 | 4.303 | .000814996 | .028548 |
| 1228 | 4.300 | .000814332 | .028536 |
| 1229 | 4.296 | .000813670 | .028525 |
| 1230 | 4.293 | .000813008 | .028513 |
| 1231 | 4.289 | .000812348 | .028501 |
| 1232 | 4.286 | .000811688 | .028490 |
| 1233 | 4.282 | .000811030 | .028478 |
| 1234 | 4.279 | .000810373 | .028467 |
| 1235 | 4.275 | .000809717 | .028455 |
| 1236 | 4.272 | .000809061 | .028444 |
| 1237 | 4.269 | .000808407 | .028433 |
| 1238 | 4.265 | .000807795 | .028421 |
| 1239 | 4.261 | .000807102 | .028409 |
| 1240 | 4.258 | .000806452 | .028398 |
| 1241 | 4.255 | .000805802 | .028387 |
| 1242 | 4.251 | .000805153 | .028375 |
| 1243 | 4.248 | .000804505 | .028364 |
| 1244 | 4.244 | .000808858 | .028352 |

## TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | *s.* | $\sqrt{s}$. |
|---|---|---|---|
| 1245 | 4.241 | .000803213 | .028341 |
| 1246 | 4.238 | .000802568 | .028329 |
| 1247 | 4.234 | .000801925 | .028318 |
| 1248 | 4.231 | .000801282 | .028307 |
| 1249 | 4.228 | .000800640 | .028295 |
| 1250 | 4.224 | .000800000 | .028284 |
| 1251 | 4.221 | .000799396 | .028273 |
| 1252 | 4.217 | .000798722 | .028262 |
| 1253 | 4.214 | .000798095 | .028250 |
| 1254 | 4.211 | .000797448 | .028239 |
| 1255 | 4.207 | .000796813 | .028228 |
| 1256 | 4.204 | .000796178 | .028217 |
| 1257 | 4.200 | .000795545 | .028205 |
| 1258 | 4.197 | .000794913 | .028194 |
| 1259 | 4.194 | .000794281 | .028183 |
| 1260 | 4.190 | .000793651 | .028172 |
| 1261 | 4.187 | .000793021 | .028161 |
| 1262 | 4.184 | .000792393 | .028149 |
| 1263 | 4.181 | .000791765 | .028138 |
| 1264 | 4.177 | .000791139 | .028127 |
| 1265 | 4.174 | .000790514 | .028116 |
| 1266 | 4.171 | .000789889 | .028105 |
| 1267 | 4.167 | .000789266 | .028094 |
| 1268 | 4.164 | .000788644 | .028083 |
| 1269 | 4.161 | .000788030 | .028072 |
| 1270 | 4.157 | .000787402 | .028061 |
| 1271 | 4.154 | .000786782 | .028050 |
| 1272 | 4.151 | .000786321 | .028038 |
| 1273 | 4.148 | .000785546 | .028027 |
| 1274 | 4.144 | .000784929 | .028016 |
| 1275 | 4.141 | .000784314 | .028006 |

### TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | *s.* | $\sqrt{s}$. |
|---|---|---|---|
| 1276 | 4 138 | .000783699 | .027995 |
| 1277 | 4.135 | .000783085 | .027984 |
| 1278 | 4.131 | .000782473 | .027973 |
| 1279 | 4.128 | .000781861 | .027962 |
| 1280 | 4.125 | .000781250 | .027951 |
| 1281 | 4.122 | .000780640 | .027940 |
| 1282 | 4.118 | .000780031 | .027929 |
| 1283 | 4.115 | .000779423 | .027918 |
| 1284 | 4.112 | .000778816 | .027907 |
| 1285 | 4.109 | .000778210 | .027896 |
| 1286 | 4.106 | .000777605 | .027886 |
| 1287 | 4.103 | .000777001 | .027875 |
| 1288 | 4.099 | .000776398 | .027864 |
| 1289 | 4.096 | .000775795 | .027853 |
| 1290 | 4.093 | .000775116 | .027841 |
| 1291 | 4.090 | .000774593 | .027831 |
| 1292 | 4.087 | .000773994 | .027821 |
| 1293 | 4.084 | .000773395 | .027810 |
| 1294 | 4.080 | .000772798 | .027799 |
| 1295 | 4.077 | .000772201 | .027789 |
| 1296 | 4.074 | .000771605 | .027778 |
| 1297 | 4.071 | .000771010 | .027767 |
| 1298 | 4.068 | .000770416 | .027756 |
| 1299 | 4.065 | .000769823 | .027746 |
| 1300 | 4.062 | .000769231 | .027735 |
| 1301 | 4.058 | .000768624 | .027724 |
| 1302 | 4.055 | .000768049 | .027714 |
| 1303 | 4.052 | .000767460 | .027703 |
| 1304 | 4.049 | .000766871 | .027692 |
| 1305 | 4.046 | .000766283 | .027682 |
| 1 06 | 4.043 | .000765697 | .027671 |

TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1307 | 4.040 | .000765111 | .027661 |
| 1308 | 4.037 | .000764526 | .027650 |
| 1309 | 4.034 | .000763942 | .027639 |
| 1310 | 4.031 | .000763359 | .027629 |
| 1311 | 4.037 | .000762776 | .027618 |
| 1312 | 4.024 | .000762195 | .027608 |
| 1313 | 4.021 | .000761615 | .027597 |
| 1314 | 4.018 | .000761035 | .027587 |
| 1315 | 4.015 | .000760456 | .027576 |
| 1316 | 4.012 | .000759878 | .027566 |
| 1317 | 4.009 | .000759301 | .027555 |
| 1318 | 4.006 | .000758725 | .027545 |
| 1319 | 4.003 | .000758150 | .027534 |
| 1320 | 4.000 | .000757576 | .027524 |
| 1321 | 3.997 | .000757002 | .027514 |
| 1322 | 3.994 | .000756430 | .027503 |
| 1323 | 3.991 | .000755858 | .027493 |
| 1324 | 3.988 | .000755217 | .027481 |
| 1325 | 3.985 | .000754717 | .027472 |
| 1326 | 3.982 | .000754148 | .027462 |
| 1327 | 3.979 | .000753579 | .027451 |
| 1328 | 3.976 | .000753012 | .027441 |
| 1329 | 3.973 | .000752445 | .027431 |
| 1330 | 3.970 | .000751880 | .027420 |
| 1331 | 3.967 | .000751315 | .027410 |
| 1332 | 3.964 | .000750751 | .027400 |
| 1333 | 3.961 | .000750187 | .027389 |
| 1334 | 3.958 | .000749625 | .027379 |
| 1335 | 3.955 | .000749064 | .037369 |
| 1336 | 3.952 | .000748503 | .027359 |
| 1337 | 3.949 | .000747943 | .027349 |

### TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1338 | 3.946 | .000747384 | .027338 |
| 1339 | 3.943 | .000746826 | .027328 |
| 1340 | 3.940 | .000746268 | .027318 |
| 1341 | 3.937 | .000745712 | .027308 |
| 1342 | 3.934 | .000745156 | .027298 |
| 1343 | 3.932 | .000744601 | .027287 |
| 1344 | 3.929 | .000744048 | .027277 |
| 1345 | 3.926 | .000743420 | .027267 |
| 1346 | 3.923 | .000742942 | .027257 |
| 1347 | 3.920 | .000742390 | .027247 |
| 1348 | 3.917 | .000741840 | .027237 |
| 1349 | 3.914 | .000741289 | .027227 |
| 1350 | 3.911 | .000740741 | .027217 |
| 1351 | 3.908 | .000740192 | .027207 |
| 1352 | 3.905 | .000739659 | .027197 |
| 1353 | 3.902 | .000739098 | .027186 |
| 1354 | 3.899 | .000738552 | .027176 |
| 1355 | 3.897 | .000738007 | .027166 |
| 1356 | 3.894 | .000737463 | .027156 |
| 1357 | 3.891 | .000736920 | .027146 |
| 1358 | 3.888 | .000736377 | .027136 |
| 1359 | 3.885 | .000735879 | .027126 |
| 1360 | 3.882 | .000735294 | .027116 |
| 1361 | 3.879 | .000734754 | .027106 |
| 1362 | 3.877 | .000734214 | .027096 |
| 1363 | 3.874 | .000733676 | .027086 |
| 1364 | 3.871 | .000733138 | .027077 |
| 1365 | 3.868 | .000732601 | .027067 |
| 1366 | 3.865 | .000732064 | .027057 |
| 1367 | 3.862 | .000731529 | .027047 |
| 1368 | 3.860 | .000730994 | .027037 |

## TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1369 | 3.857 | .000730460 | .027027 |
| 1370 | 3.854 | .000729927 | .027017 |
| 1371 | 3.851 | .000729395 | .027007 |
| 1372 | 3.848 | .000728863 | .026997 |
| 1373 | 3.846 | .000728332 | .026988 |
| 1374 | 3.843 | .000727802 | .026978 |
| 1375 | 3.840 | .000727273 | .026968 |
| 1376 | 3.837 | .000726744 | .026958 |
| 1377 | 3.834 | .000726216 | .026948 |
| 1378 | 3.832 | .000725689 | .026939 |
| 1379 | 3.829 | .000725163 | .026929 |
| 1380 | 3.826 | .000724638 | .026919 |
| 1381 | 3.823 | .000724113 | .026909 |
| 1382 | 3.821 | .000723589 | .026899 |
| 1383 | 3.818 | .000723066 | .026890 |
| 1384 | 3.815 | .000722543 | .026880 |
| 1385 | 3.812 | .000722022 | .026870 |
| 1386 | 3.809 | .000721501 | .026861 |
| 1387 | 3.807 | .000720981 | .026851 |
| 1388 | 3.804 | .000729461 | .026841 |
| 1389 | 3.801 | .000729942 | .026832 |
| 1390 | 3.799 | .000719424 | .026822 |
| 1391 | 3.796 | .000718907 | .026812 |
| 1392 | 3.793 | .000718391 | .026803 |
| 1393 | 3.790 | .000717875 | .026793 |
| 1394 | 3.788 | .000717360 | .026784 |
| 1395 | 3.785 | .000716846 | .026774 |
| 1396 | 3.782 | .000716332 | .026764 |
| 1397 | 3.779 | .000715819 | .026755 |
| 1398 | 3.777 | .000715308 | .026745 |
| 1399 | 3.774 | .000714796 | .026736 |

## TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1400 | 3.771 | .000714286 | .026726 |
| 1401 | 3.769 | .000713776 | .026717 |
| 1402 | 3.766 | .000713267 | .026707 |
| 1403 | 3.763 | .000712758 | .026698 |
| 1404 | 3.761 | .000712251 | .026688 |
| 1405 | 3.758 | .000711744 | .026679 |
| 1406 | 3.755 | .000711238 | .025669 |
| 1407 | 3.753 | .000710732 | .026659 |
| 1408 | 3.750 | .000710227 | .026650 |
| 1409 | 3.747 | .000709723 | .026641 |
| 1410 | 3.745 | .000709220 | .0[illegible]6631 |
| 1411 | 3.742 | .000708717 | .026622 |
| 1412 | 3.739 | .000708215 | .026612 |
| 1413 | 3.737 | .000707714 | .026603 |
| 1414 | 3.734 | .000707213 | .026593 |
| 1415 | 3.731 | .000706714 | .026584 |
| 1416 | 3.729 | .000706215 | .026575 |
| 1417 | 3.726 | .000705716 | .026565 |
| 1418 | 3.724 | .000705218 | .026556 |
| 1419 | 3.721 | .000704722 | .026547 |
| 1420 | 3.718 | .000704225 | .026537 |
| 1421 | 3.716 | .000703730 | .026528 |
| 1422 | 3.713 | .000703235 | .026519 |
| 1423 | 3.710 | .000702741 | .026509 |
| 1424 | 3.708 | .000702247 | ·026500 |
| 1425 | 3.705 | .000701754 | ·026491 |
| 1426 | 3.703 | .000701262 | .026481 |
| 1427 | 3.700 | .000700708 | .026472 |
| 1428 | 3.697 | .000700280 | .026463 |
| 1429 | 3.695 | .000699790 | .026454 |
| 1430 | 3.692 | .000699300 | .026444 |

## TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1431 | 3.690 | .000698812 | .026535 |
| 1432 | 3.687 | .000698324 | .026426 |
| 1433 | 3.685 | .000698837 | .026417 |
| 1434 | 3.682 | .000697350 | .026407 |
| 1435 | 3.680 | .000696864 | .026398 |
| 1436 | 3.677 | .000696379 | .026389 |
| 1437 | 3.674 | .000695894 | .026380 |
| 1438 | 3.672 | .000695410 | .026371 |
| 1439 | 3.669 | .000694927 | .026361 |
| 1440 | 3.667 | .000694444 | .026352 |
| 1441 | 3.664 | .000693963 | .026343 |
| 1442 | 3.662 | .000693481 | .026334 |
| 1443 | 3.659 | .000693001 | .026325 |
| 1444 | 3.657 | .000692521 | .026316 |
| 1445 | 3.654 | .000692042 | .026307 |
| 1446 | 3.651 | .000691563 | .026298 |
| 1447 | 3.649 | .000691085 | .026288 |
| 1448 | 3.646 | .000690608 | .026279 |
| 1449 | 3.644 | .000690131 | .026270 |
| 1450 | 3.641 | .000689655 | .026261 |
| 1451 | 3.639 | .000689180 | .026252 |
| 1452 | 3.636 | .000688705 | .026243 |
| 1453 | 3.634 | .000688231 | .026234 |
| 1454 | 3.631 | .000687758 | .026225 |
| 1455 | 3.629 | .000687285 | .026216 |
| 1456 | 3.626 | .000686813 | .026207 |
| 1457 | 3.624 | .000686342 | .029198 |
| 1458 | 3.621 | .000685871 | .026189 |
| 1459 | 3.619 | .000685401 | .026180 |
| 1460 | 3.617 | .000684931 | .026171 |
| 1461 | 3.614 | .000684463 | .026162 |

## TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1462 | 3.612 | .000683994 | .026153 |
| 1463 | 3.609 | .000683527 | .026144 |
| 1464 | 3.607 | .000683060 | .026135 |
| 1465 | 3.604 | .000682594 | .026126 |
| 1466 | 3.602 | .000682128 | .026118 |
| 1467 | 3.599 | .000681663 | .026109 |
| 1468 | 3.597 | .000681199 | .026100 |
| 1469 | 3.594 | .000680735 | .026091 |
| 1470 | 3.592 | .000680272 | .026082 |
| 1471 | 3.589 | .000679810 | .026073 |
| 1472 | 3.587 | .000679348 | .026064 |
| 1473 | 3.585 | .000678887 | .026055 |
| 1474 | 3.582 | .000678426 | .026047 |
| 1475 | 3.580 | .000677966 | .026038 |
| 1476 | 3.577 | .000677507 | .026029 |
| 1477 | 3.575 | .000677048 | .026020 |
| 1478 | 3.572 | .000676590 | .026011 |
| 1479 | 3.570 | .000676132 | .026003 |
| 1480 | 3.568 | .000675676 | .025994 |
| 1481 | 3.565 | .000675220 | .025985 |
| 1482 | 3.563 | .000674764 | .025976 |
| 1483 | 3.560 | .000674309 | .025967 |
| 1484 | 3.558 | .000673854 | .025959 |
| 1485 | 3.556 | .000673401 | .025950 |
| 1486 | 3.553 | .000672948 | .025941 |
| 1487 | 3.551 | .000672495 | .025933 |
| 1488 | 3.548 | .000672043 | .025924 |
| 1489 | 3.546 | 000671592 | .025915 |
| 1490 | 3.544 | .000671141 | .025907 |
| 1491 | 3.541 | .000670020 | .025898 |
| 1492 | 3.539 | .000670241 | .025889 |

## TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | *s.* | $\sqrt{s}.$ |
|---|---|---|---|
| 1493 | 3.537 | .000669792 | .025880 |
| 1494 | 3.534 | .000669344 | .025872 |
| 1495 | 3 532 | .000668896 | .025863 |
| 1496 | 3.529 | .000668449 | .025854 |
| 1497 | 3.527 | .000668003 | .025846 |
| 1498 | 3.525 | .000667557 | .025837 |
| 1499 | 3.522 | .000667111 | .025828 |
| 1500 | 3.520 | .000666666 | .025820 |
| 1501 | 3.518 | .000666222 | .025811 |
| 1502 | 3.515 | .000665779 | .025803 |
| 1503 | 3.513 | .000665336 | .025794 |
| 1504 | 3.511 | .000664894 | .025786 |
| 1505 | 3.508 | .000664452 | .025777 |
| 1506 | 3.506 | .000664106 | .025768 |
| 1507 | 3.504 | .000663570 | .025760 |
| 1508 | 3.501 | .000663130 | .025751 |
| 1509 | 3.499 | .000662691 | .025743 |
| 1510 | 3.497 | .000662252 | .025734 |
| 1511 | 3.494 | .000661813 | .025726 |
| 1512 | 3.492 | .000661376 | .025717 |
| 1513 | 3.490 | .000660938 | .025709 |
| 1514 | 3.487 | .000660502 | .025700 |
| 1515 | 3.485 | .000660066 | .025691 |
| 1516 | 3.483 | .000659631 | .025683 |
| 1517 | 3.481 | .000659196 | .025675 |
| 1518 | 3.478 | .000658761 | .025666 |
| 1519 | 3.476 | .000658328 | .025658 |
| 1520 | 3.474 | .000657895 | .025649 |
| 1521 | 3.471 | .000657462 | .025641 |
| 1522 | 3.469 | .000657030 | .025633 |
| 1523 | 3.467 | .000656599 | .025624 |

### TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| **1524** | 3.465 | .000656168 | .025616 |
| **1525** | 3.462 | .000655737 | .025607 |
| **1526** | 3.460 | .000655308 | .025599 |
| **1527** | 3.458 | .000654879 | .025591 |
| **1528** | 3.456 | .000654450 | .025582 |
| **1529** | 3.453 | .000654022 | .025579 |
| **1530** | 3.451 | .000653595 | .025566 |
| **1531** | 3.449 | .000653168 | .025557 |
| **1532** | 3.447 | .000652741 | .025549 |
| **1533** | 3.444 | .000652316 | .025540 |
| **1534** | 3.442 | .000651890 | .025532 |
| **1535** | 3.440 | .000652117 | .025524 |
| **1536** | 3.438 | .000651042 | .025516 |
| **1537** | 3.435 | .000650618 | .025507 |
| **1538** | 3.433 | .000650195 | .025499 |
| **1539** | 3.431 | .000649773 | .025491 |
| **1540** | 3.429 | .000649351 | .025482 |
| **1541** | 3.426 | .000648930 | .025474 |
| **1542** | 3.424 | .000648502 | .025466 |
| **1543** | 3.422 | .000648988 | .025457 |
| **1544** | 3.420 | .000647668 | .025449 |
| **1545** | 3.417 | .000647275 | .025441 |
| **1546** | 3.415 | .000646831 | .025433 |
| **1547** | 3.413 | .000646412 | .025425 |
| **1548** | 3.411 | .000645995 | .025416 |
| **1549** | 3.409 | 000645578 | .025408 |
| **1550** | 3.407 | .000645161 | .025400 |
| **1551** | 3.404 | .000644745 | .025392 |
| **1552** | 3.402 | .000644330 | .025384 |
| **1553** | 3.400 | .000643915 | .025375 |
| **1554** | 3.398 | .000643501 | .025367 |

## Table 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1555 | 3.396 | .000643087 | .025359 |
| 1556 | 3.394 | .000642674 | .025351 |
| 1557 | 3.392 | .000642261 | .025343 |
| 1558 | 3.389 | .000641848 | .025335 |
| 1559 | 3.387 | .000641437 | .025327 |
| 1560 | 3.385 | .000641025 | .025318 |
| 1561 | 3.382 | .000640615 | .025310 |
| 1562 | 3.380 | .000640205 | .025302 |
| 1563 | 3.378 | .000633397 | .025294 |
| 1564 | 3.376 | .000639386 | .025286 |
| 1565 | 3.374 | .000638978 | .025278 |
| 1566 | 3.372 | .000638570 | .025270 |
| 1567 | 3.370 | .000638162 | .025262 |
| 1568 | 3.367 | .000637755 | .025254 |
| 1569 | 3.365 | .000637349 | .025246 |
| 1570 | 3.363 | .000636943 | 025238 |
| 1571 | 3.361 | .000636537 | .025230 |
| 1572 | 3.359 | .000636132 | .025222 |
| 1573 | 3.357 | .000635728 | .025214 |
| 1574 | 3.355 | .000635324 | .025206 |
| 1575 | 3.352 | .000634921 | .025198 |
| 1576 | 3.350 | .000634518 | .025190 |
| 1577 | 3.348 | .000634115 | .025182 |
| 1578 | 3.346 | .000633714 | .025174 |
| 1579 | 3.344 | .000633312 | .025166 |
| 1580 | 3.342 | .000632911 | .025158 |
| 1581 | 3.340 | .000632511 | .025150 |
| 1582 | 3.338 | .000632112 | .025142 |
| 1583 | 3.335 | .000631712 | .025134 |
| 1584 | 3.333 | .000631313 | .025126 |
| 1585 | 3.331 | .000630915 | .025118 |

## TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1586 | 3.329 | .000630517 | .025110 |
| 1587 | 3.327 | .000630120 | .025102 |
| 1588 | 3.325 | .000629323 | .025094 |
| 1589 | 3.323 | .000629327 | .025086 |
| 1590 | 3.321 | .000628931 | .025078 |
| 1591 | 3.319 | .000628535 | .025071 |
| 1592 | 3.317 | .000628141 | .025063 |
| 1593 | 3.315 | .000627746 | .025055 |
| 1594 | 3.312 | .000627353 | .025047 |
| 1595 | 3.310 | .000626959 | .025039 |
| 1596 | 3.308 | .000626566 | .025031 |
| 1597 | 3.306 | .000626174 | .025023 |
| 1598 | 3.304 | .000625782 | .025016 |
| 1599 | 3.302 | .000625391 | .025008 |
| 1600 | 3.300 | .000625000 | .025000 |
| 1601 | 3.298 | .000624609 | .024992 |
| 1602 | 3.296 | .000624220 | .024984 |
| 1603 | 3.294 | .000623805 | .024976 |
| 1604 | 3.292 | .000623441 | .024969 |
| 1605 | 3.290 | .000623053 | .024961 |
| 1606 | 3.288 | .000622655 | .024953 |
| 1607 | 3.286 | .000622277 | .024946 |
| 1608 | 3.284 | .000621891 | .024938 |
| 1609 | 3.282 | .000621504 | .024930 |
| 1610 | 3.280 | .000621118 | .024922 |
| 1611 | 3.277 | .000620732 | .024915 |
| 1612 | 3.275 | .000620347 | .024907 |
| 1613 | 3.273 | 000619963 | .024899 |
| 1614 | 3.271 | .000619579 | .024891 |
| 1615 | 3.269 | .000619195 | .024884 |
| 1616 | 3.267 | .000618812 | .024876 |

## Table 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1617 | 3.265 | .000618429 | .024868 |
| 1618 | 3.263 | .000618047 | .024861 |
| 1619 | 3.261 | .000617665 | .024853 |
| 1620 | 3.259 | .000617284 | .024845 |
| 1621 | 3.257 | .000616903 | .024838 |
| 1622 | 3.255 | .000616523 | .024830 |
| 1623 | 3.253 | .000616143 | .024822 |
| 1624 | 3.251 | .000615764 | .024815 |
| 1625 | 3.249 | .000615384 | .024807 |
| 1626 | 3.247 | .000615006 | .024799 |
| 1627 | 3.245 | .000614628 | .024792 |
| 1628 | 3.243 | .000614251 | .024784 |
| 1629 | 3.241 | .000613874 | .024776 |
| 1630 | 3 239 | .000613497 | .024769 |
| 1631 | 3 237 | .000613121 | .024761 |
| 1632 | 3.235 | .000612746 | .024754 |
| 1633 | 3.233 | .000612370 | .024746 |
| 1634 | 3.231 | .000611995 | .024789 |
| 1935 | 3.229 | .000611621 | .024731 |
| 1636 | 3.227 | .000611247 | .024723 |
| 1637 | 3.225 | .000610874 | .024716 |
| 1638 | 3.223 | .000610501 | .024708 |
| 1639 | 3.222 | .000610128 | .024701 |
| 1640 | 3.220 | .000609756 | .024693 |
| 1641 | 3.218 | .000609385 | .024686 |
| 1642 | 3.216 | .000609013 | .024678 |
| 1543 | 3.214 | .000608643 | .024671 |
| 1644 | 3.212 | .000608273 | .024664 |
| 1645 | 3.210 | .000607900 | .024656 |
| 1646 | 3.208 | .000607527 | .024648 |
| 1647 | 3.206 | .000607164 | .024641 |

## Table 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1648 | 3.204 | .000606801 | .024633 |
| 1649 | 3.202 | .000606428 | .024626 |
| 1650 | 3.200 | .000606060 | .024618 |
| 1651 | 3.198 | .000605694 | .024612 |
| 1652 | 3.196 | .000605327 | .024603 |
| 1653 | 3.194 | .000604961 | .024596 |
| 1654 | 3.192 | .000604595 | .024589 |
| 1655 | 3.190 | .000604230 | .024581 |
| 1656 | 3.188 | .000603865 | .024574 |
| 1657 | 3.186 | .000603500 | .024566 |
| 1658 | 3.185 | .000603133 | .024559 |
| 1659 | 3.183 | .000602773 | .024551 |
| 1660 | 3.181 | .000602409 | .024544 |
| 1661 | 3.179 | .000602047 | .024537 |
| 1662 | 3.177 | .000601685 | .024529 |
| 1663 | 3.175 | .000601323 | .024522 |
| 1664 | 3.173 | .000600962 | .024515 |
| 1665 | 3.171 | .000600601 | .024507 |
| 1666 | 3.169 | .000600240 | .024500 |
| 1667 | 3.167 | .000599880 | .024492 |
| 1668 | 3.165 | .000599520 | .024485 |
| 1669 | 3.164 | .000599161 | .024478 |
| 1670 | 3.162 | .000598802 | .024470 |
| 1671 | 3.160 | .000598444 | .024463 |
| 1672 | 3.158 | .000598086 | .024456 |
| 1673 | 3.156 | .000597729 | .024448 |
| 1674 | 3.154 | .000597371 | .024441 |
| 1675 | 3.152 | .000597015 | .024434 |
| 1676 | 3.150 | .000596659 | .024427 |
| 1677 | 3.148 | .000596303 | .024420 |
| 1678 | 3.147 | .000595948 | .024413 |

## TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1679 | 3.145 | .000595593 | .024405 |
| 1680 | 3.143 | .000595238 | .024398 |
| 1681 | 3.141 | .000594884 | .024390 |
| 1682 | 3.139 | .000594530 | .024383 |
| 1683 | 3.137 | .000594177 | .024376 |
| 1684 | 3.135 | .000593824 | .024369 |
| 1685 | 3.134 | .000593472 | .024361 |
| 1686 | 3.132 | .000593102 | .024354 |
| 1687 | 3.130 | .000592768 | .024347 |
| 1688 | 3.128 | .000592417 | .024340 |
| 1689 | 3.126 | .000592066 | .024332 |
| 1690 | 3.124 | .000591717 | .024325 |
| 1691 | 3.122 | .000591366 | .024318 |
| 1692 | 3.121 | .000501017 | .024311 |
| 1693 | 3.119 | .000590667 | .024304 |
| 1694 | 3.117 | .000590319 | .024297 |
| 1695 | 3.115 | .000589471 | .024290 |
| 1696 | 3.113 | .000589622 | .024282 |
| 1697 | 3.111 | .000589275 | .024275 |
| 1698 | 3.110 | .000588928 | .024268 |
| 1699 | 3.108 | .000588582 | .024261 |
| 1700 | 3.106 | .000588235 | .024254 |
| 1701 | 3.104 | .000587889 | .024246 |
| 1702 | 3.102 | .000587545 | .024239 |
| 1703 | 3.100 | .000587199 | .024232 |
| 1704 | 3.099 | .000586854 | .024225 |
| 1705 | 3.097 | .000586510 | .024218 |
| 1706 | 3.095 | .000586166 | .024211 |
| 1707 | 3.093 | .000585823 | .034204 |
| 1708 | 3.091 | .000585480 | .024197 |
| 1709 | 3.090 | .000585138 | .024190 |

## TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1710 | 3.088 | .000584795 | .024183 |
| 1711 | 3.086 | .000584453 | .024175 |
| 1712 | 3.084 | .000548112 | .024168 |
| 1713 | 3.083 | .000583771 | .024161 |
| 1714 | 3.081 | .000583431 | .024154 |
| 1715 | 3.079 | .000583090 | .024147 |
| 1716 | 3.077 | .000582751 | .024140 |
| 1717 | 3.075 | .000582411 | .024133 |
| 1718 | 3.073 | .000582072 | .024126 |
| 1719 | 3.072 | .000581734 | .024119 |
| 1720 | 3.070 | .000581395 | .024112 |
| 1721 | 3.068 | .000581058 | .024105 |
| 1722 | 3.066 | .000580720 | .024098 |
| 1723 | 3.064 | .000580384 | .024091 |
| 1724 | 3.063 | .000580046 | .024084 |
| 1725 | 3.061 | .000579710 | .024077 |
| 1726 | 3.060 | .000579374 | .024070 |
| 1727 | 3.058 | .000579039 | .024063 |
| 1728 | 3.056 | .000578704 | .024056 |
| 1729 | 3.054 | .000578369 | .024049 |
| 1730 | 3.052 | .000578035 | .024042 |
| 1731 | 3.050 | .000577701 | .024035 |
| 1732 | 3.048 | .000577367 | .024028 |
| 1733 | 3.047 | .000577034 | .024021 |
| 1734 | 3.045 | .000576701 | .024015 |
| 1735 | 3.043 | .000576369 | .024008 |
| 1736 | 3.041 | .009576037 | .024001 |
| 1737 | 3.040 | .000575705 | .023994 |
| 1738 | 3.038 | .000275374 | .028987 |
| 1739 | 3.036 | .000575043 | .023980 |
| 1740 | 3.035 | .000574712 | .023973 |

### Table 7.—Slopes.

| Slope, one in | Feet, per mile. | $s.$ | $\sqrt{s.}$ |
|---|---|---|---|
| 1741 | 3.033 | .000574382 | .023966 |
| 1742 | 3.031 | .000574053 | .023959 |
| 1743 | 3.029 | .000572723 | .023953 |
| 1744 | 3.028 | .000573394 | .023946 |
| 1745 | 3.026 | .000573066 | .023939 |
| 1746 | 3.024 | .000572738 | .023932 |
| 1747 | 3.022 | .000572410 | .023925 |
| 1748 | 3.021 | .000572082 | .023918 |
| 1749 | 3.019 | .000571755 | .023911 |
| 1750 | 3.017 | .000571429 | .023905 |
| 1751 | 3.015 | .000571102 | .023898 |
| 1752 | 3.014 | .000570776 | .023891 |
| 1753 | 3.012 | .000570451 | .023884 |
| 1754 | 3.010 | .000570160 | .023878 |
| 1755 | 3.009 | .000569801 | .023871 |
| 1756 | 3.007 | .000569476 | .023864 |
| 1757 | 3.005 | .000569152 | .023857 |
| 1758 | 3.003 | .000568828 | .023850 |
| 1759 | 3.002 | .000568584 | .023843 |
| 1760 | 3.000 | .000568182 | .023837 |
| 1761 | 2.998 | .000567859 | .023830 |
| 1762 | 2.997 | .000567537 | .023823 |
| 1763 | 2.995 | .000567215 | .023816 |
| 1764 | 2.993 | .000566893 | .023809 |
| 1765 | 2.992 | .000566572 | .023803 |
| 1766 | 2.990 | .000566251 | .023796 |
| 1767 | 2.988 | .000565931 | .023789 |
| 1768 | 2.986 | .000565612 | .023783 |
| 1769 | 2.985 | .000565291 | .023776 |
| 1770 | 2.983 | .000564972 | .023769 |
| 1771 | 2.981 | .000564653 | .023762 |

## Table 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1772 | 2.980 | .000564334 | .023756 |
| 1773 | 2.978 | .000564016 | .023749 |
| 1774 | 2.976 | .000563692 | .023742 |
| 1775 | 2.975 | .000563380 | .023736 |
| 1776 | 2.973 | .000563063 | .023729 |
| 1777 | 2.971 | .000562746 | .023722 |
| 1778 | 2.969 | .000562430 | .023716 |
| 1779 | 2.968 | .000562114 | .023709 |
| 1780 | 2.966 | .000561798 | .023702 |
| 1781 | 2.965 | .000561482 | .023696 |
| 1782 | 2.963 | .000561168 | .023689 |
| 1783 | 2.961 | .000560852 | .023682 |
| 1784 | 2.960 | .000560538 | .023676 |
| 1785 | 2.958 | .000560224 | .023662 |
| 1786 | 2.956 | .000559910 | .023663 |
| 1787 | 2.955 | .000559597 | .023656 |
| 1788 | 2.953 | .000559284 | .023649 |
| 1789 | 2.951 | .000558972 | .023643 |
| 1790 | 2.950 | .000558659 | .023636 |
| 1791 | 2.948 | .000558347 | .023629 |
| 1792 | 2.946 | .000558036 | .023623 |
| 1793 | 2.945 | .000557724 | .023616 |
| 1794 | 2 943 | .000557414 | .023610 |
| 1795 | 2.942 | .000557103 | .023603 |
| 1796 | 2.940 | .000556793 | .023596 |
| 1797 | 2.938 | .000556483 | .023589 |
| 1798 | 2.937 | .000556173 | .023583 |
| 1799 | 2.935 | .000555864 | .023577 |
| 1800 | 2.933 | .000555555 | .023570 |
| 1801 | 2.932 | .000555247 | .023564 |
| 1802 | 2.930 | .000554939 | .023557 |

## TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1803 | 2.928 | .000554631 | .023551 |
| 1804 | 2.927 | .000554324 | .023544 |
| 1805 | 2.925 | .000554017 | .023538 |
| 1806 | 2.924 | .000553798 | .023531 |
| 1807 | 2.922 | .000553403 | .023525 |
| 1808 | 2.920 | .000553097 | .023518 |
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| 1810 | 2.917 | .000552486 | .023505 |
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| 1816 | 2.908 | .000550661 | .023466 |
| 1817 | 2.906 | .000550358 | .023460 |
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| 1827 | 2.890 | .000547344 | .023395 |
| 1828 | 2.888 | .000547046 | .023389 |
| 1829 | 2.887 | .000546747 | .023383 |
| 1830 | 2.885 | .000546448 | .023376 |
| 1831 | 2.884 | .000546150 | .023370 |
| 1832 | 2.882 | .000545852 | .023363 |
| 1833 | 2.881 | .000545554 | .023357 |

## TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1834 | 2.879 | .000545256 | .023351 |
| 1835 | 2.877 | .000544949 | .023344 |
| 1836 | 2.876 | .000544662 | .023338 |
| 1837 | 2.874 | .000544437 | .023331 |
| 1838 | 2.873 | .000544096 | .023325 |
| 1839 | 2.871 | .000543774 | .023319 |
| 1840 | 2.870 | .000543478 | .023313 |
| 1841 | 2.868 | .000543183 | .023306 |
| 1842 | 2.866 | .000542888 | .023300 |
| 1843 | 2.865 | .000542594 | .023294 |
| 1844 | 2.863 | .000542299 | .023287 |
| 1845 | 2.862 | .000542005 | .023281 |
| 1846 | 2.860 | .000541712 | .023275 |
| 1847 | 2.859 | .000541419 | .023268 |
| 1848 | 2.858 | .000541126 | .023262 |
| 1849 | 2.856 | .000540833 | .023256 |
| 1850 | 2.854 | .000540541 | .023250 |
| 1851 | 2.853 | .000540249 | .023243 |
| 1852 | 2.851 | .000539957 | .023237 |
| 1853 | 2.849 | .000539611 | .023230 |
| 1854 | 2.848 | .000539374 | .023224 |
| 1855 | 2.847 | .000539084 | .023218 |
| 1856 | 2.845 | .000538793 | .023212 |
| 1857 | 2.843 | .000538503 | .023206 |
| 1858 | 2.842 | .000538213 | .023199 |
| 1859 | 2.840 | .000537924 | .023193 |
| 1860 | 2.839 | .000537633 | .023187 |
| 1861 | 2.837 | .000537346 | .023181 |
| 1862 | 2.836 | .000537057 | .023174 |
| 1863 | 2.834 | .000536769 | .023168 |
| 1864 | 2.833 | .000536481 | .023162 |

### TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | *s.* | $\sqrt{s.}$ |
|---|---|---|---|
| 1865 | 2.831 | .000536193 | .023156 |
| 1866 | 2.830 | .000535906 | .023150 |
| 1867 | 2.828 | .000535613 | .023143 |
| 1868 | 2.827 | .000535332 | .023137 |
| 1869 | 2.825 | .000535046 | .023131 |
| 1870 | 2.822 | .000534759 | .023125 |
| 1871 | 2.822 | .000534474 | .023119 |
| 1872 | 2.821 | .000534188 | .023112 |
| 1873 | 2.819 | .000533903 | .023106 |
| 1874 | 2.818 | .000533618 | .023100 |
| 1875 | 2.816 | .000533333 | .023094 |
| 1876 | 2.815 | .000533049 | .023088 |
| 1877 | 2.813 | .000532765 | .023082 |
| 1878 | 2.812 | .000532481 | .023076 |
| 1879 | 2.810 | .000532198 | .023069 |
| 1880 | 2.809 | .000531915 | .023063 |
| 1881 | 2.807 | .000531632 | .023057 |
| 1882 | 2.806 | .000531344 | .023051 |
| 1883 | 2.804 | .000531067 | .023045 |
| 1884 | 2.803 | .000530785 | .023039 |
| 1885 | 2.801 | .000530504 | .023033 |
| 1886 | 2.800 | .000530223 | .023027 |
| 1887 | 2.798 | .000529940 | .023020 |
| 1888 | 2.797 | .000529661 | .023014 |
| 1889 | 2.795 | .000529381 | .023008 |
| 1890 | 2.794 | .000529101 | .023002 |
| 1891 | 2.792 | .000528821 | .022996 |
| 1892 | 2.791 | .000528541 | .022990 |
| 1893 | 2.789 | .000528262 | .022984 |
| 1894 | 2.788 | .000527983 | .022978 |
| 1895 | 2.786 | .000527705 | .022972 |

TABLE 7.—Slopes.

| Slope, one in | Feet, per mile. | $s$. | $\sqrt{s}$. |
|---|---|---|---|
| 1896 | 2.785 | .000527426 | .022966 |
| 1897 | 2.783 | .000527148 | .022960 |
| 1898 | 2.782 | .000526870 | .022954 |
| 1899 | 2.780 | .000526593 | .022948 |
| 1900 | 2.779 | .000526316 | .022942 |

TABLE 8.—Comparison of coefficients ($c$) in the formula.

$$V = c\sqrt{rs}.$$

D'Arcy's coefficient for clean pipes under pressure.—Kutter's coefficients for pipes flowing full with $n=.011$ and $s=.001$.

| Diameter. Ft. | Ins. | D'Arcy's Coefficients for clean pipes. | Kutter's Coefficient, $n=.011$. $s=.001$. |
|---|---|---|---|
| 0 | 5 | 103.8 | 82.9 |
| 0 | 6 | 105.3 | 87.4 |
| 0 | 7 | 106.4 | 91.5 |
| 0 | 8 | 107.2 | 95.0 |
| 0 | 9 | 107.9 | 97.9 |
| 0 | 10 | 108.5 | 100.5 |
| 0 | 11 | 108.9 | 103.3 |
| 1 | 0 | 109.3 | 105.7 |
| 1 | 2 | 109.9 | 109.5 |
| 1 | 4 | 110.4 | 113.0 |
| 1 | 6 | 110.7 | 116.2 |
| 1 | 8 | 111.0 | 118.8 |
| 1 | 10 | 111.3 | 121.3 |

TABLE 8.

| Diameter. Ft. | Ins. | D'Arcy's Coefficients for clean pipes. | Kutter's Coefficient, $n = .011$. $s = .001$. |
|---|---|---|---|
| 2 | 0 | 111.5 | 123.6 |
| 2 | 3 | 111.7 | 126.5 |
| 2 | 6 | 111.9 | 129.1 |
| 2 | 9 | 112,1 | 131.5 |
| 3 | 0 | 112.2 | 133.6 |
| 3 | 3 | 112.3 | 135.6 |
| 3 | 6 | 112.4 | 137.2 |
| 3 | 9 | 112.5 | 138.8 |
| 4 | 0 | 112.6 | 140.4 |
| 4 | 3 | 112.7 | 141.7 |
| 4 | 6 | 112.7 | 143.0 |
| 5 | 0 | 112.8 | 145.4 |
| 5 | 6 | 112.9 | 147.6 |
| 6 | 0 | 113.0 | 149.5 |
| 6 | 6 | 113.0 | 151.2 |
| 7 | 0 | 113.1 | 152.7 |
| 8 | 0 | 113.2 | 155.4 |
| 9 | 0 | 113.2 | 157.7 |
| 10 | 0 | 113.3 | 159.7 |

TABLE 9.—Of coefficients ($c$) from the formulæ of D'Arcy, Kutter and Fanning for small pipes below 5 inches in diameter.

$$V = c\sqrt{rs}.$$

| Diameter in inches | ($c$) D'Arcy's Co-efficient for clean pipes. | ($c$) Kutter's Co-efficient from formula $n = .011$ $s = .001$ | ($c$) Kutter's Co-efficient recommended by L. D. A. Jackson. | ($c$) Fanning's Co-efficient for clean iron pipes. |
|---|---|---|---|---|
| 0 ⅜ | 59.4 | 32.0 | 82.9 | |
| ½ | 65.7 | 36.1 | 82.9 | |
| ¾ | 74.5 | 42.6 | 82.9 | |
| 1 | 80.4 | 47.4 | 82.9 | 80.4 |
| 1¼ | 84.8 | 51.9 | 82.9 | |
| 1½ | 88.1 | 55.4 | 82.9 | 88.0 |
| 1¾ | 90.7 | 58.8 | 82.9 | 92.5 |
| 2 | 92.9 | 61.5 | 82.9 | 94.8 |
| 2½ | 96.1 | 66.0 | 82.9 | |
| 3 | 98.5 | 70.1 | 82.9 | 96.6 |
| 4 | 101.7 | 77.4 | 82.9 | 103.4 |
| 5 | 103.8 | 82.9 | 82.9 | |

**Table 10.—Showing the velocity in feet per second in pipes, by Kutter's formula (6) and also by the tables, the value of $n$ being .011.**

| Diameter, | | Slope, | Velocity, | Velocity, |
|---|---|---|---|---|
| Feet. | Inches. | one in | by Kutter's formula. | by Flynn's tables. |
| 1 | 0 | 66 | 6.62 | 6.51 |
| 1 | 0 | 2640 | 1.02 | 1.03 |
| 2 | 0 | 66 | 10.89 | 10.75 |
| 2 | 0 | 2640 | 1.67 | 1.70 |
| 4 | 0 | 66 | 17.52 | 17.28 |
| 4 | 0 | 2640 | 2.70 | 2.73 |
| 6 | 0 | 66 | 22.63 | 22.54 |
| 6 | 0 | 2640 | 3.54 | 3.56 |

Table 11.—Showing the velocity in feet per second in pipes, by Kutter's formula (6) and also by the tables, the value of $n$ being .013.

| Diameter, Feet. | Diameter, Inches. | Slope, one in | Velocity, by Kutter's formula. | Velocity, by Flynn's tables. |
|---|---|---|---|---|
| 1 | 0 | 66 | 5.34 | 5.25 |
| 1 | 0 | 2640 | 0.81 | 0.83 |
| 2 | 0 | 66 | 8.91 | 8.80 |
| 2 | 0 | 2640 | 1.36 | 1.39 |
| 4 | 0 | 66 | 14.44 | 14.34 |
| 4 | 0 | 2640 | 2.24 | 2.27 |
| 6 | 0 | 66 | 18.91 | 18.82 |
| 6 | 0 | 2640 | 2.94 | 2.98 |

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